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EUROPEAN FRIT FLY IN NORTH AMERICA

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INTRODUCTION

The investigations reported in the following pages were made at La Fayette, Ind., except as otherwise indicated, in the years 1914–1916. They relate to the European frit fly, an insect which attacks both winter and spring wheat every year over the whole geographical range of the crop and at times has done considerable damage. This fly has received little study in this country on account of its minute size, the difficulty of carrying it through its life cycle in cages, and the confused and uncertain condition of its classification, which made it impossible to tell how many species were involved. The similarity of its attack to that of the Hessian fly has also, no doubt, in many cases prevented its recognition as a grain pest.

HISTORY AND SYNONYMY

In 1750 a paper was presented by Linnaeus (*13*),[1] the celebrated naturalist, to the Swedish Academy of Sciences, in which he described the injury caused to barley in Sweden by the larvæ of a small black fly which he found was destroying the immature kernels of the grain to a serious extent, in many heads eating out almost every kernel. Such light and worthless kernels the Swedes called "frits." The species was not given a scientific name until 1758, when the same writer (*14, p. 598*) described it as *Musca frit.* Fabricius (*7, p. 216*) in 1805 included the species under Oscinis, and it has generally been known as *Oscinis frit* since that date.

A century after the species had been described, it was found that the larvæ of the late fall brood winter as stem miners in winter grain, chiefly rye, in Europe, and that spring grain, especially rye and oats, is attacked in the same way by the spring brood. The summer brood was found to attack the kernels of oats more commonly than those of barley. These differences were for a long time supposed to indicate that several, at

[1] Reference is made by number (italics) to "Literature cited," pp. 472-473.

least two, species were involved; but finally a substantial agreement has been attained in the belief that the damage is the work of the single species, *Oscinis frit.*

In the United States the first biological observations on the species were made by H. Garman (*10*) in Kentucky in the fall of 1889, when he found the stems of young wheat infested. James Fletcher (*8; 9, p. 158*) made the same observation at Ottawa, Canada, at about the same time, and also reared the fly from larvæ in stems of several grasses. Both of these entomologists mention the insect as *Oscinis variabilis* Loew, a species described from North America.

In 1896 Lugger (*17*) reported the insect as *Oscinis variabilis* Loew, injuring spring wheat in Minnesota.

In 1898 Coquillett (*4*) reported various rearings of what he identified as *Oscinis carbonaria* Loew (*15, 16*) and *O. soror* Macquart. F. M. Webster (*21*) also reported rearing the same two species from various plants in 1903, his specimens having been identified by Coquillett.

Tucker (*19*) described a dark form from Colorado in 1908 as *Oscinis nigra*, without reference to its habits.

In 1912 a monograph on the Oscinidae (or Chloropidae, as he called them) of North America was published by Theodor Becker (*2*), of Liegnitz, Prussia, one of the most eminent specialists on this group. His work was based almost entirely on material furnished from this country by Prof. A. L. Melander, of Pullman, Wash., and the writer. Becker identified *Oscinis frit* from North America for the first time, with its variety or color form *O. pusilla* (see Meigen *18, v. 6, p. 157*, and *p. 160* for *Chlorops pusilla* and *C. frit*). What had been called *O. carbonaria* he made a synonym of *O. nitidissima*, a European species described by Meigen (*6, p. 388*) in 1838, which he regarded as distinct from *O. frit.*

Criddle (*6*) in 1913 discussed the larval habits in Manitoba, believing that he had detected three summer broods.

Starting with North American material identified by Becker as *Oscinis frit, O. pusilla*, and *O. nitidissima*, and with European material identified as *O. frit* by Prof. M. Bezzi and by Rev. Gabriel Strobl, the writer has made a study of the North American forms. This has extended to: (a) An examination of the type material of *O. variabilis, O. carbonaria, O. nigra*, and many other more or less related species; (b) a study of reared and collected material in most of the larger collections of the United States and Canada, including numerous rearings by members of the Bureau of Entomology staff and nearly 16,000 specimens of the species swept from vegetation in various parts of the United States and Canada; (c) the rearing of more than 300 specimens from several different food plants; and (d) a comparative study of the male genitalia in North American and European material, including some bred from oats in England.

This study has led to the conclusion that *Oscinis pusilla, O. nitidissima, O. carbonaria, O. variabilis, O. nigra* Tucker, and *O. soror* Macquart are all synonyms of *O. frit*. The multiplicity of names has arisen from the variability and wide distribution of the species. The long-continued confusion has existed mainly because the taxonomists since Linnaeus who have classified the adults have paid little or no attention to the habits, while the biological workers have been uninformed as to the characters used in classification and have applied whatever name was given them.

Typical *Musca frit* as defined by Linnaeus has the femora and tibiæ wholly black; *Oscinis nigra* Tucker is precisely this, as described from Denver, Colo. This extreme form apparently does not occur east of the Rocky Mountain region but is common westward. *O. frit* as recognized by Becker, however, includes eastern and western forms with a small amount of yellow on the tibiæ, at base and tip. When the yellow portions are more extensive, so that the front and middle tibiæ are merely ringed with black, the form *O. pusilla* is reached, of which *O. carbonaria* is an exact synonym. From this form *O. variabilis* differs only in having a more shining thorax and is the same as *O. nitidissima* of Europe, North American specimens having been so identified by Becker. All gradations from the somewhat shining dorsal surface of *O. frit* to the highly shining one of *O. nitidissima* can be readily found. Coquillett separated some specimens with shorter frontal triangle as *O. soror* of Macquart, but this is also a variable character; moreover, Macquart in describing it said nothing about the species having a short triangle.

NATURE OF INJURY

In the commonest form of injury minute maggots occur in young stems of wheat close to the ground. They are easily distinguished from the larvæ of the Hessian fly (*Phytophaga destructor* Say) from the fact that the larva is in the center of the stem and crawls actively when removed, whereas the Hessian-fly larva is between the bases of the leaves and is extremely inactive. The *Oscinis frit* larva often causes the central leaf to die and turn brown, those about it remaining green; this the Hessian fly larva never does.

DISTRIBUTION IN NORTH AMERICA

The region of greatest abundance of the frit fly in North America corresponds rather closely with that in which winter wheat is grown, from the Great Lakes to the Ohio River, and westward about as far as the Missouri. But outside this area it is often common locally from the Atlantic to the Pacific and from Ottawa, Canada, to the Gulf of Mexico. The fly occurs generally wherever grass is abundant and remains green for a considerable part of the year. So in the arid West it occurs in spots, along streams or in irrigated pastures, or in the higher altitudes where

the humidity is greater. Sweepings by the writer in 1917 gave numerous specimens at Pass Christian, Miss., and Lake Charles, La. A few were found at Marfa, Tex., Las Cruces, N. Mex., and Tucson, Ariz.; but none at Yuma, Ariz. Other species replace this one on grass at San Diego and Los Angeles, Calif., but it extends from San Francisco as far south as Santa Barbara. In Canada *Oscinis frit* occurs but sparingly in Manitoba, Saskatchewan, and Alberta but is much more numerous in the more southern latitude of Ontario and Quebec. No records are available for the extreme East. It has been reported from Juneau, Alaska, latitude about 58°. This is the farthest north of all existing North American records.

The accompanying map (fig. 1) has been dotted to indicate the distribution and approximately the abundance of the species, although in

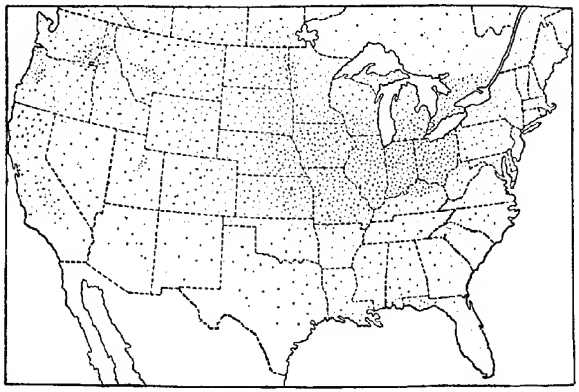

FIG. 1.—Map showing distribution of *Oscinis frit*.

many parts it is marked more from analogy than from definite information.

DESCRIPTION OF INSTARS

EGG

The eggs (fig. 2) are pure white, measuring 0.7 mm. in length and 0.178 mm. in greatest diameter, approximately straight on one side, the other more curved. The surface bears nearly 20 fine ridges, running lengthwise, which are occasionally broken.

NEWLY HATCHED LARVA

The larva (fig. 3) upon emerging from the egg measures 1.06 mm. in length and 0.14 mm. in greatest diameter. It is whitish and semitransparent in color, without head, rather pointed in front and truncate behind. A pair of very minute, soft, 2-jointed antennæ are present. The

only firm structures are the two mouth hooks and the frame to which they are attached. The hooks are clear reddish brown in color. The frame is black at their attachment and becomes gradually less chitinized and paler farther back, and more concealed by the mass of muscles surrounding it. Figure 3 shows one-half of this double structure. The hooks work on a pivot at the point marked *x* in the figure. The larva has 11 segments, the sutures between them, except the first three, bearing transverse rows of very fine teeth below, which extend up the sides in a narrowing series. The first segment is encircled by several rows of these minute teeth, evidently of use in entering crevices. At this stage there appear to be no anterior spiracles, the only ones being a pair at the posterior end; these are on raised protuberances bearing a circle of branched hairs standing at right angles to the axis, the opening into the air tube being on the inner side, not the tip, of the protuberance. From each spiracle a conspicuous air tube extends forward along the side of the body.

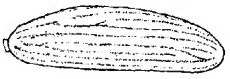

FIG. 2.—Egg of *Oscinis frit*: × 65.

FULL-GROWN LARVA

The full-grown larva (fig. 4) measures about 3 mm. in length and 0.4 mm. in greatest diameter. It is distinctly yellow in color on account of the accumulation of fat under the integument, for use during transformation. The antennæ and mouth hooks (fig. 5)) are relatively smaller than

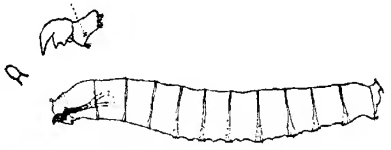

FIG. 3.—Newly hatched larva of *Oscinis frit*. ×65. Antenna and mouth-hooks more enlarged, the latter showing fulcrum at *x*.

in the first stage. The mouth hooks are strongly curved, black, with several microscopic teeth on the under side. Anterior spiracles occur on the first segment, consisting of a protuberance bearing a half dozen soft lobes in a vertical row. The posterior spiracles appear to occupy a median position on their protuberances, with less distinct circles of hairs.

Intermediate larval stages were not made out.

PUPA

Like many Diptera, this species forms the pupa within the hardened larval integument, called the puparium. The pupa is never visible unless this shell-like covering is removed. It is white at first, becoming black

as the time of emergence draws near. It shows the organs of the adult in rough outline, the wings, however, being represented by very small rudiments.

PUPARIUM

This is at first yellow in color, turning to brown, and is usually opaque. It is 2.7 mm. in length by 0.9 mm. in breadth, bearing the minute larval spiracles anteriorly on each side of its tip and the posterior ones behind.

FIG. 4.—Full-grown larva of *Oscinis frit*. × 36.

Neither of these is functional, since they do not connect with the spiracles of the pupa. (Pl. 57, B.)

ADULT (PL. 57, A)

The following description of the adult has been drawn up with the aim of including all common variations.

MALE AND FEMALE

Length 1.1 to 2 mm. Head, thorax, and abdomen black. Front in well-matured specimens wider than one eye, usually a little narrower in specimens not completely hardened before killing. Frontal triangle shining black, reaching usually almost to the root of the antennæ, but shorter in many specimens, at shortest only a little over half the length of front; the remainder of the front outside the triangle is opaque black.

FIG. 5.—*Oscinis frit*: Mouth hooks of full-grown larva. More enlarged than in figure 4.

Face black, rather concave, its lower edge sometimes yellowish. Vertex bearing one outwardly directed, minute bristle near the corner of the eye; a minute, convergent pair of ocellars, and behind them a pair of also convergent ones on the occiput; a row of three or four small hairs along the inner edge of the eye in the opaque part of the front; a pair of hairs at the edge of the mouth also. Antennæ black, third joint rather large, round; the arista with very minute pubescence, beyond its basal fourth often lighter in color, rarely almost white when viewed against a dark background. Proboscis and palpi black. Bucca (side of head below eye) usually about one-sixth the height of the eye, but varying from one-fourth to one-tenth or less, the cause of this variation being usually the greater or less drawing up of the under part of the head in drying.

Thorax with length, breadth, and height about equal; dorsum subshining to shining, with minute dark hairs usually arranged in rows lengthwise. One pair of minute dorsocentral bristles before the scutellum, far apart; one supra-alar, two or three notopleural, one humeral, all small. Scutellum of ordinary form, neither flattened nor elongated. Pleuræ shining black, without bristles. Halteres yellow.

Abdomen black, subshining, rarely the first segment yellowish; the black color extending underneath to the soft part, which is usually paler. Male genitalia often protrude, showing a pair of distinct claspers curved backward, but these may be retracted and invisible. Abdomen of female pointed, ending in a minute pair of palpus-like organs, at tip of the telescopic, 3-jointed ovipositor when the latter is extended (fig. 6), but ordinarily so retracted as to be barely visible.

Legs of ordinary structure; coxæ and femora black, the trochanters and knees often yellowish; tibiæ rarely entirely black, usually paler at base and tip, the fore and middle tibiæ often wholly yellow, hind ones, however, always with at least a black ring. Tarsi yellow, darkened toward tips.

Wings subhyaline, sometimes a little brownish, varying moderately in width; costa extending to fourth vein; the costal segment between the tips of the first and second veins about 1½ times as long as the following one; fourth vein ending very slightly behind the apex; anal angle well developed.

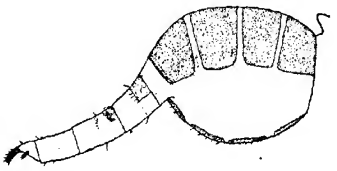

FIG. 6.—*Oscinis frit:* Female abdomen, distended with eggs and ovipositor protruded. (From alcoholic specimen, highly magnified.)

MALE GENITALIA

Since these organs in many insects throw a great deal of light on the limits of species, the genitalia of about 25 males were mounted for study after being boiled for from 5 to 10 minutes in 10 per cent caustic potash; among these were 5 specimens of the oat fly from Carforth, England, kindly furnished by Prof. T. H. Taylor, of Leeds University; others were from Missoula, Mont., Sioux City, Iowa, and La Fayette, Ind. No appreciable difference was found in any of these. The general features are shown in figure 7, drawn from a specimen taken at Missoula, Mont.

The fifth abdominal segment in the male is very small and normally retracted so as to be invisible. The sixth segment is also small, rather cup-shaped, open behind and below, and at least its posterior part is visible in life. It bears a symmetrical pair of long claspers below, curving backward and toward the middle line. The anus is situated at the middle of the segment behind; and on each side of this is a protruding, strongly chitinized lobe, which is produced forward inside both above and below; the upper arm keeps close to the side of the cavity and joins the produced upper margin of a curved plate with a thickened edge, which extends forward so as to form a trough, almost a tube, through the open anterior end of which the penis projects. This organ arises in the ventral part of the sixth segment in the median line and is supported in part from the ventral forward extension of the lobe beside the anus.

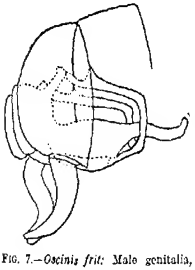

FIG. 7.—*Oscinis frit:* Male genitalia, highly magnified.

LIFE HISTORY

SUMMARY

At La Fayette, Ind., *Oscinis frit* winters in the larval stage in winter wheat. Following the emergence of this brood as adults in the spring, there are four summer broods.

DETAILED STUDIES

METHODS

On account of the minute size of the fly and its disinclination to lay eggs in cages, considerable difficulty was encountered in running a series of broods through the season, as well as in obtaining other details. The methods which finally proved successful are, therefore, believed to be of sufficient importance to justify a rather full description.

Wheat sown in the garden in September, 1915, became infested that fall. On March 30 and April 11, 1916, portions of it were dug up, placed in pans of earth, and covered with glass cylinders 8 inches in diameter with cheesecloth tops. Records of spring emergence were made from these. In removing the adults, advantage was taken of their natural inclination to go to light. The cage was opened in the house close to a south window on which the sun was shining. The flies, as soon as given their freedom, would fly toward the window, alight on a swiss curtain before it, and begin to walk upward. They were then easily secured in numbered homeopathic vials, in each of which a small drop of sirup and one of water had previously been placed. In these vials, tightly corked, adults were kept for some time, frequently 20 days or more, and in one instance 49, by changing the vial occasionally.

Breeding cages were prepared by placing earth known to be free from insects in 6-inch flowerpots, planting about 10 kernels of wheat close together in the middle of each, and covering with a lantern globe topped with cheesecloth. In seven or eight days under outdoor summer conditions the wheat was from 1 to 2 inches high, the proper stage for introducing the flies. A male and female were placed in the same vial and introduced into the cage by simply tipping up the lantern globe and setting the vial upright in the earth, removing the thumb from the mouth of the vial just as the globe was replaced. This method was not quite satisfactory, but only a few flies escaped. Their inclination to walk upward caused them to leave the vial at once if it was upright, but if it was horizontal they sometimes remained in it a long time, and even failed entirely to find their way out.

In the cage the flies were inactive most of the time, usually resting on the cloth at the top but occasionally visiting the plants, where they appeared to lick up a nutritious exudation. The addition of sirup did not lengthen their lives, and they soon died in cages without plants.

Eggs were obtained in a small proportion of cages, in from 20 to 40 per cent, as a rule. Many flies laid only 1 or 2 eggs, and the maximum was about 10. Since the normal number of eggs maturing in the ovaries of a female at one time is about 30, it is evident that the conditions were far from satisfactory; but they were the only ones under which any eggs were obtained.

On account of the small number of eggs secured, each successive generation in cages was much smaller than the preceding one. It is therefore necessary to start the season with a large supply of material to avoid running out before the end. With this species, though perhaps not with related forms, it is easy to stock up with adults of the first summer brood by placing considerable quantities of already infested garden winter wheat under cages as early as June 1. This wheat will yield adults in the desired numbers to stock cages for the second brood. Wheat taken from the fields is likely to be much less infested than that sown in gardens; the latter therefore should be used for cages.

Larvæ on hatching from eggs in cages immediately entered the young wheat stems and in most cases were allowed to develop there, the pot being watered and kept under observation to see when the adults made their appearance. For early larval stages, eggs were taken from leaves and placed in a vial, where they could be examined more frequently and closely than in the cage. In this way the newly hatched larvæ were obtained before they had fed. For later stages, larvæ were dissected out of wheat stems they had entered, placed on a fresh piece of young stem, and corked up in a vial. Larvæ so handled readily entered the second stem, which would keep fresh for four or five days; a second transfer would bring the larva to maturity—some, in fact, matured without it. The process of dissecting the larva out was performed under a low power of the binocular dissecting microscope, using a needle with a minute hook at tip and slitting the stem carefully. This is a simpler process than the description might indicate and was performed successfully hundreds of times with only a few mishaps. During the summer of 1915 as many as 100 vials containing transferred larvæ were under observation at once. The vigor and endurance of the larvæ are remarkable. When the stems were left too long in the vials and decayed, the larvæ almost always survived. In several cases they endured starvation for several days; one fasted a week and then when given the opportunity entered a wheat stem and in due time reached maturity. They do not survive drying up, however, but require a moist atmosphere. This is true also of the adults.

WINTER BROOD: DATES OF SPRING EMERGENCE

Records were kept in the spring of 1916 on four cages containing garden wheat that had wintered outdoors where it grew. The emergence is shown in Table I.

TABLE I.—*Emergence of winter brood of Oscinis frit*

Date of emergence.[a]	Cage No. 2, caged Mar. 30.	Cage No. 3, caged Mar. 30.	Cage No. 4, caged Apr. 11.	Cage No. 5, caged Apr. 11.	Total by days.
Apr. 26	1	0	0	0	1
29	0	0	0	0	0
30	0	0	1	5	6
May 3	5	3	0	10	18
6	2	0	2	9	13
9	0	1	1	4	6
15	1	0	1	3	5
19	0	0	0	0	0
25	0	0	1	0	1
31	0	0	0	0	0
June 12	0	0	0	0	0
Total by cages	9	4	6	31	50

[a] Dates on which no observations were made are not entered in the table.

From Table I it appears that emergence in 1916 extended over a period of 29 days (April 26 to May 25) and that 85 per cent of the flies emerged in 11 days, from April 30 to May 10. It would appear, however, that these dates were retarded by keeping the cages too much in the shade, since sweepings made outdoors at frequent intervals in early April gave the first adult for 1916 on April 13 and for 1915 on April 14.

SUMMER BROODS

Four complete summer broods were reared in 1916, as reported in Table II. Each cage was started at the time indicated by the cross, using flies that had emerged a few days before. Cages 23, 24, and 26 were exceptions, being stocked with garden wheat already heavily infested outdoors, This explains their large yield of flies. The wheat in cage 26 was taken up so late (June 16) that there was a possibility of its containing eggs of the second brood; and this probably accounts for the single fly which emerged in it on July 28, 16 days after the last preceding one. The negative observations for each cage are omitted up to the first positive one, after that both positive and negative are included up to the time that the use of the cage was discontinued. All cages that produced no positive results are omitted; they were more numerous than those included.

Flies of the first summer brood began to emerge on June 12 and continued to do so until July 13 (32 days), the heaviest emergence being from June 25 to 30.

Flies of the second summer brood began to emerge July 16 and continued to do so until July 26 (only 11 days). Flies emerged in 10 cages. July 21 gave the largest record.

Flies of the third summer brood emerged from August 10 to August 28 in 5 cages, a total, however, of only 21 flies.

TABLE II.—*Record of adults of Oscinis frit reared in cages at La Fayette, Ind., in the summer of 1916*

[The sign X indicates dates on which flies were introduced into cage. Observations were then made daily until the first fly emerged and thereafter only on dates indicated]

Date of observation.	Brood I. Cage No. —										Brood II. Cage No. —										Brood III. Cage No—					Brood IV. Cage No. —	
	11	13	14	15	19	20	21	23	24	26	27	28	29	31	36	39	43	44	45	52	73	74	75	82	84	87	92
May 6	X																										
9		X	X	X																							
15					X	X	X																				
31								X	X																		
June 12		2																									
13		1																									
14		1																									
15		0																									
16		1								X																	
18	2	1	1	1																							
19		0	0	0				1			X	X	X														
20		1		2																							
21	0			1					4																		
22	0	2	0	0					3					X													
23	2	2	2	1			1	5	4	2																	
26	0	6	0	0	1		8	26	41	1																	
27	0	1	0	0	0		0		21	2					X	X	X	X	X								
29	0						0	31	20	16										X							
July 2	0	1	0	0	0	1	0	9	0	7																	
5	0	0	0	0	0	0	0	10	3	13																	
6								1																			
7	0	0	0	0	0	0	0	1	7	8																	
10	0	0	0	0	0	0	0	0	1	7																	
13	0	0	0	0	0	0	0	1	1	4																	
16	0	0	0	0	0	0	0	0	0	0	1																
17								0	0	0	0	4	1														
19								0			0	0	3	1	4	1			1								
21									0	0	0	0	0	1	4	3	3	2	1	2	X	X	X	X			
24											0	1	0	0	0	1	0	0	2	0							
26											0	0	0	0	1	0	1	1	1	1							
28										1	0	0	0	0	0	0	0	0	0	0					X		
29										0																	
30											0	0	0	0	0	0	0	0	0	0							
Aug. 1											0	0	0	0	0	0	0	0	0	0							
3											0	0	0	0	0	0	0	0	0	0							
7											0	0	0	0	0	0	0	0	0	0							
10															0	0	0	0	0	0		3					
11																					1	1					
12																					0	0	1				
14																					0	0	0				
16																					0	0	0			X	
17																											X
19																					2	0	0				
21																					0	0	0	3			
23																					1	0	0	2	3		
24																					0	0	0	0	1		
26																					0	0	0	0	2		
28																					0	0	0	0	1		
31																					0	0	0	0	0		
Sept. 3																					0	0	0	0	0		
6																					0	0	0	0	0		
8																					0	0	0	0	0		
11																					0	0	0	0	0		
14																								0	0		
24																										1	1
25																										1	0
26																										0	2
27																										0	0
Oct. 2																										0	0
3																										0	1
4																										0	0
6																										0	0
10																										0	0
13																										0	0
15																										0	0

Only two flies of the fourth summer brood were obtained. These emerged in cage 87 on September 24 and 25. The small number was due to the rapid dwindling of the broods in cages, as explained under "Methods" p. 459. When a possible failure to get the fourth brood in lineal descent was anticipated, a supplementary series of cages was started, stocked with flies obtained by sweeping a bluegrass lawn. One of these, cage 92, gave adults, and they correspond very well with those of cage 87, the first fly appearing on the same date in both. Cage 92 gave two adults on September 26 and one, the last of the season, on October 3.

Cages started the last of September with flies swept from the lawn and with the few reared flies gave no results, no eggs being obtained. The weather was cool, and the flies were almost continuously dormant. Afterthought would suggest that in spring and fall the cages need a good deal of direct sunlight. No indications, however, of a fifth summer brood were observed. Flies emerging in September probably live longer than those of midsummer, having long dormant periods in cool weather; so they merely lay eggs on winter wheat in October for the winter brood.

The record here given covers too few flies, and those kept under too uniform conditions, to exclude the possibility that a portion of the representatives of this species, under natural conditions, might have a brood more or less. It does indicate, however, that four is the normal number of summer broods; and, allowing for the effect of a slight retardation in the cages in spring and fall, it is probable that five broods in the season will occur oftener than three.

LENGTH OF INSTARS

The number of days from adult to adult in each of the summer broods is shown by Table III.

In this table there were 8 individuals in brood II and 3 in brood III whose parents emerged two days apart, the intermediate day being taken as the date for both. One of these cases in brood III gave the minimum record of 22 days. The actual minimum period for the season was for the male of this pair. He was 21 days from emergence when his offspring emerged; but since his mate was 23 days old the number 22 was recorded as the average. The period covered in this case for the male was July 21 to August 11, in which there were two hot waves separated by a few somewhat cooler days—on the whole, an excessively hot period.

The table shows an average period from adult to adult in the first summer brood of 49.7 days for 35 individuals; for the second brood, 30.3 days for 41 individuals; for the third brood, 28.5 days for 21 individuals; and for the fourth brood, 45.5 days for 2 individuals.

TABLE III.—*Variation in the time of emergence of adults of Oscinis frit in each brood, with reference to the number of days from emergence of their parents*

Number of days since emergence of parents.	Brood number.				Total by days.
	I.	II.	III.	IV.	
22			1		1
24		1	4		5
25			1		
26		10			10
27		3			3
28		4	3		7
29		5	1		6
30		1	5		6
31		4	2		6
32		3	2		5
33		1	1		2
34			1		1
35		4			4
36		1			1
40		3			3
42		1			1
44	3				3
45				1	1
46	3			1	4
47	3				3
48	2				2
49	6				6
52	16				16
53	1				1
58	1				1
Total by broods	35	41	21	2	99
Average	49.7	30.3	28.5	45.5	

The period from adult to adult may be considered as consisting of: (a) The preoviposition period; (b) the egg instar; (c) larval instars; and (d) the pupal instar. Since the sum of these (adult to adult) varied from 21 to 58 days, naturally the components would vary accordingly—not, however, in strict proportion, because all periods become successively accelerated while approaching the heat climax of summer and are retarded after passing it. Making the best approximation possible, the records obtained seem to bear out the following division of the entire period:

	PERCENTAGE OF TIME IN LIFE CYCLE
Preoviposition	14
Egg	11
Larva	50
Pupa	25
Total	100

It would be more logical to count this period from egg to egg, but oviposition is very difficult to observe and the data upon that subject are very meager. The emergence of the adult is the easiest point to note, and is the one on which the record is most complete.

HABITS AND FOOD PLANTS

As indicated in the introduction, the fly deposits its eggs on grains and grasses, usually on the very young and tender shoots, but sometimes upon or within the glumes just after heading. In the former case the larva enters the shoot and feeds downward in the middle; in the latter, it eats out the soft young kernel

Oviposition was not observed, although eggs were found that had been laid only an hour or two. In one instance, a female was seen to protrude the three terminal segments of her abdomen into a sort of ovipositor (see fig. 6, from an alcoholic specimen). With this she explored the crevices along the stem formed by overlapping of leaves but finally discontinued the operation without laying. Eggs were found both on the stem close to the ground and on the leaves, the latter, however, always within 3 or 4 inches of the ground. One or two lots were laid in crevices, but most of them were in plain sight. In about 5 days after the emergence of the female her eggs are fully developed and can be seen through the thin side walls of the abdomen. There are normally about 30 of equal size contained in the two ovaries. No indication was seen that other series might develop later, but such may be the case under outdoor conditions.

During the seasons of 1915 and 1916, sweepings were made on various grains and grasses, both by the writer and by a number of voluntary assistants,[1] to ascertain the distribution and preferences of the adult. Usually 200 sweeps with a 12-inch net were made. An examination of 240 lots was made in 1915 and of 310 lots in 1916, in order to sort out the various species of oscinids and related families. In both years *Oscinis frit* led all others in numbers, with totals of 4,677 and 11,235 out of grand totals of 23,416 and 40,187.

In the course of this work it soon became manifest that adults of *Oscinis frit* are rare on grain after it has begun to shoot up to head, or on grasses that are approaching maturity; but they are abundant on wheat and grass that is in an earlier stage, stooling or producing fresh shoots. Bluegrass lawns that are kept sprinkled and mowed yield large records of *O. frit* practically all through the season. Roadside bluegrass kept grazed yields large numbers before the dry weather of summer, but the records decrease rapidly at this time. Evidently the fly seeks grain or grass that is producing new shoots. They seem to be attracted by an exudation from the fresh epidermis, which they greedily lick, and not by the desire to lay their eggs on the plants. In no case was any appreciable number of specimens obtained from sweeping on dicotyledons, unless the stand was noticeably mixed with grass. The maximum record for 1915 was 365 flies in 200 sweeps with a 10-inch net on a blue-

[1] Among these should be mentioned Mr. Norman Criddle, Field Officer for Manitoba of the Dominion Entomological Branch, C. N. Ainslie, Sioux City, Iowa, and Dr. C. F. Adams, Atherton, Mo.

grass lawn at Elk Point, S. Dak., by C. N. Ainslie. This was on September 7.

This was exceeded five times in 1916, when the highest record was 486 flies in 200 sweeps with a 13½-inch net on bluegrass lawn at the Central Experiment Farms, Ottawa, Canada, by Mr. Germain Beaulieu, on August 17. Both of these records indicate a great concentration of the flies upon this food plant in late summer. However, an earlier record stood second in 1916, when Dr. C. F. Adams swept 401 flies in 200 sweeps of a 12-inch net at Atherton, Mo., on bluegrass lawn, on May 17.

INFESTATION OF WHEAT

Almost all the infestation observed by the writer has been upon wheat. Eggs are laid on fall wheat soon after it comes up, and the larvæ winter in the stems. Wheat was sown at weekly intervals from September 12 to October 17, and in November it was noted that the infestation was great in the earliest sowing and decreased regularly to the latest one or two sowings, in which none could be seen. In the spring the wheat is attacked by the first summer brood. Spring wheat is not a farm crop at La Fayette, but experimental sowings, especially the later ones, were heavily attacked.

A very characteristic symptom of infestation in young shoots of all kinds is the dying of the central leaf while the others around it remain green. The observer readily notices this when once his attention is directed to it. In the cooler and moister periods of the year, however, the insect may be abundant and yet only a few of the plants show this symptom. Since the larva does not usually cut the central leaf entirely off, in periods of low transpiration the leaf will still keep green for some time, whereas the same injury in hotter and dryer weather would kill the leaf at once. So the damage may be greater than it appears and can be calculated for the cool part of the year only by placing a known number of plants in a cage and counting the flies that emerge, every one of which may be considered to have destroyed a shoot.

At a meeting of Russian economic entomologists in Kiev in 1913, Mr. N. V. Kurdjumov (*1*) advanced the theory that the pruning off of some of the shoots of summer grain by *Oscinis frit* may do it good rather than harm. But the same author (*12*) in the same year mentions the insect as inflicting particularly severe injury upon spring grain. Since several other Russian entomologists have reported it to be doing serious injury, it is likely that its possibly useful character was mentioned in a qualified way.

Although in garden-sown wheat infestation occurred in a considerable percentage of the stems, the writer was never able to find in fields of winter wheat any appreciable infestation in late fall or early spring, such as was reported by Garman. For a while this was explained apparently by the fact that at these seasons of the year the characteristic

symptom of infestation (the dying of the central shoot) does not appear so quickly. In the spring of 1917 the point was further tested by transplanting wheat from fields to pots under cages, to compare it with rye and several grasses treated in the same way. Glass cylinders were placed over several grasses outdoors without transplanting, and several lots of wheat and grass were taken into the laboratory and all the stems slit up to find larvæ. The net result was that the fly was found to winter in timothy and meadow fescue, but not in wheat, rye, or several other grasses. The explanation which best harmonizes this result with other observed facts is that the insect has a rather wide range of habits and may concentrate upon any one of several food plants, just as it sometimes severely attacks the young, unripe grains while ordinarily it does not affect them.

INFESTATION OF RYE

A small percentage of infestation was obtained in rye sown in the garden rather late in spring. The European literature contains frequent references to *Oscinis frit* as a pest of rye, but the crop is so little raised in the United States that the insect heretofore has escaped notice in this connection.

INFESTATION OF BARLEY

Linnaeus (*13*) in his classic first paper on *Musca frit* described the infestation of barley kernels on an extensive scale, beyond anything that has been seen since. He estimated that one-fifth of the barley crop was annually destroyed by the insect. A few years later in another paper he reduced the estimate to one-tenth, indicating that further observation had not shown so great infestation as in the first instance. The insect also attacks barley stems in the spring, as indicated in European literature and confirmed by the writer.

INFESTATION OF OATS

The oat fly is a term used in England for *Oscinis frit*. Wilhelm (*24*) published a 40-page pamphlet in Germany on it, using the same name (die Haferfliege). In both countries it has often been noted mining the young shoots and destroying the ripening kernels. Westwood (*22*, *23*) reports a striking instance of infestation of oat kernels in England, attributing it to *O. atricilla* Zett. A farmer had thrashed 25 quarters of oats and stored them in a loft. The following account was written to Westwood by J. B. Yonge, Esq.

> A few days afterwards a stratum of flies was seen on top of the Oats, coming up among them, and passing away through the window. The stratum was about 4 feet long, 1 broad, and 3 inches thick, and being continually renewed from below as those above passed off, an immense number must have gone through during the four days it was observed.

This case compares very well with the immense infestation of barley kernels reported by Linnaeus in 1750 (*13*); no doubt both represent extreme instances of this sort of damage.

Professor T. H. Taylor, of the Department of Agriculture, Leeds University, England, has kindly given the following summary of his observations on the oat fly in England in a letter dated October 6, 1915.[1]

The chief attack is made upon the oat crop. I have seen crops very seriously damaged by the pest. The attack that injures the oat plants most seriously is caused by the first brood appearing in early summer. These flies lay their eggs on the leaves of the young oat corn and the larvæ bore in the heart of the plant and destroy the stem. The plant thereupon tillers and produces a stunted bunch of young shoots which are practically worthless. The farmers call this condition of the oats "segging." The second brood of flies remains mostly—but perhaps not altogether—upon the oat crop, and the larvæ attack the *grains* between the glumes. These larvæ pupate *in situ* and the flies (third generation) migrate from the oats to wild grasses, upon which they spend the winter, pupating the following spring and giving rise to the first brood of frit-flies for the new season, thus completing the vicious circle. I have come across isolated examples of frit-fly attacking the stem of wheat and barley, but as I have paid very little attention to these outside attacks I can only say that they appeared to be due to the ordinary *frit*. I do not remember to have seen the grains between the glumes of either wheat or barley attacked.

When the writer's studies early revealed the fact that the American species has a marked distaste for the oat, several lines of investigation were carried out in order to test this relation as fully as possible.

(1) Wheat, rye, emmer, barley, and oats, sowed in rows in the garden in late spring, were infested in the order given, wheat much the worst, oats hardly at all. Oats sowed in the garden on August 25 were taken up and placed in a cage on September 20, when they were about 10 inches high and very thrifty. They had occupied a rather dense row about 25 feet long. In this cage only one specimen of *Oscinis frit* emerged, on October 16. A control cage of wheat sowed at the same time and caged at the same time yielded 68 adults of *O. frit*—12 on October 5, 20 on October 13, 8 on October 16, 20 on October 22, 3 on October 27, and 5 on November 1.

(2) Eight cages were started in which pairs of *Oscinis frit* were confined on young oat plants. Three eggs were laid in two cages, but no adults developed.

(3) In order to learn whether the American species is able to feed upon the oat stem at all, on September 10 and 13, 1915, 29 larvæ were dissected out of young wheat stems and placed on similar young oat stems in vials, as described under "Methods," p. 459, except that the food plant was changed. The results are shown in Table IV.

In most instances the larvæ which did not enter lived about a week, crawling actively on the glass much of the time.

[1] Professor Taylor disclaims any attempt to identify the species of the insect; specimens sent by him at the same time, however, seem indistinguishable from *Oscinis frit* as identified by Professor Bezzi and C. Strobl.

TABLE IV.—*Results of transferring larvæ of Oscinis frit from young wheat stems to young oat stems*

Larva No.	Result.
176	Died without entering oat stem.
177	Do.
178	Do.
179	Do.
180	Do.
186	Do.
187	Do.
188	Do.
189	Do.
190	Do.
199	Do.
200	Do.
201	Do.
202	Refused to enter oat stem, and after 7 days the nearly starved larva was placed in a vial with a wheat stem, which it entered and in due time emerged as a normal adult, Oct. 15.
203	Refused to enter oat stem, and after 10 days the nearly starved larva was placed in a vial with a wheat stem; it was however too weak to enter, and soon died.
204	Entered oat stem and fed; pupated normally; its emergence was not noted in the record.
205	Died without entering oat stem.
206	Do.
207	Do.
208	Entered and fed normally, and adult emerged Oct. 15.
209	Entered and fed, but left stem to wander on glass; however pupated and emerged Oct. 14.
210	Died without entering oat stem.
211	Do.
212	Entered and fed, but died without pupating.
213	Died without entering oat stem.
214	Do.
216	Larva was nearly full-grown and pupated without entering oat stem.
217	Died without entering oat stem.
218	Larva was nearly full-grown, and pupated apparently without feeding.

Thus it appears, disregarding larvæ 216 and 218, that out of 27 larvæ transferred, only 4 (204, 208, 209, and 212) accepted the oat as a food plant, and 1 of these did not reach pupation; 2 of the 4, however, emerged as adults and showed no differences from specimens reared entirely upon wheat.

A control series on the same dates, in which larvæ were dissected out of wheat stems and placed in vials on other wheat stems, gave the results recorded in Table V.

Of the 13 larvæ transferred in this test, only 3 died without entering the wheat stem, 7 went through their transformations normally, while the failure to get an emergence record for the remaining 3 probably is not due to the transfer. It may be presumed that in both series some larvæ suffered unnoticed injuries while they were being removed from the stems. The net result of the two series shows that larvæ of the American species, when they have once begun to feed in wheat, are very loath

to accept the oat, usually preferring starvation, whereas they can be transferred to new wheat stems with comparative ease.

TABLE V.—*Results of transferring larvæ of Oscinis frit from wheat stems to other wheat stems*

Larva No.	Result.
181	Fed normally, and adult emerged.
182	Do.
183	Do.
184	Fed and developed to pupation, but pupa became moldy and adult never emerged.
185	Died without entering.
191	Fed normally, and adult emerged.
192	Do.
193	Fed normally and developed to pupation, emergence not noted.
194	Died without entering.
195	Entered stem normally but was accidentally killed later while being transferred to fresh stem.
196	Fed normally, and adult emerged.
197	Died without entering.
198	Fed normally, and adult emerged.

(4) To determine whether specimens of *Oscinis frit* that had been reared in wheat would breed in green oat kernels, a bunch of newly headed oat plants was transplanted into a pan and arranged so that the heads only would project up through a slot in a horizontal wide board; an 8-inch glass cylinder, topped with cheesecloth, was placed over the heads, and the slot in the board was filled up and chinked with cotton batting. Into this cage with the oat heads 28 specimens of both sexes of the fly were introduced on July 2. On the next day 4 more pairs were introduced. None of the flies lived in this cage more than a week. On August 10 a single adult emerged, the only offspring of the 36 specimens confined.

(5) To test whether *Oscinis frit* or any other oscinid normally lives in oat kernels in the United States, it was planned to strip the green oats from 50 heads (estimated to be at least 1,000 kernels) and place them in a lantern-globe cage to see if any flies would emerge. The cooperation of economic entomologists was obtained, and in all 79 lots of 50 heads each were placed in cages. Twenty-two lots were from various places in northern Indiana; 2 from Madison, Wis.; 10 from Minnesota, sent by Professor Ruggles; 3 from South Dakota, sent by Mr. Severin; 7 from places in Montana, sent by Messrs. Cooley, J. R. Parker, and Larrimer; 4 from Washington, sent by Professor Melander; 5 from Utah, sent by Professor Titus; 13 from Colorado, sent by Director Gillette; 4 from Sioux City, Iowa, sent by C. N. Ainslie; and 9 lots received without data, but apparently from the West. The material was in various stages, but none fully ripe. It represented numerous varieties of oats, some being almost

pure wild oats. In only 2 lots did any flies emerge. One of these was taken at Manchester Siding, Ind., near Crawfordsville, on July 13 and yielded one specimen of *O. frit* on July 26. The other lot was taken on the edge of Crawfordsville the same day, and on July 26 it was found that two specimens of *O. frit* had emerged, together with one of *O. umbrosa* Loew and two of *Elachiptera nigriceps* Loew, a member of the same family.

A fair conclusion from the five lines of investigation would seem to be that *Oscinis frit*, as we have it in this country, does not normally feed upon the oat at all, but that occasional individuals, when compelled, are able to do so. This conclusion, in view of the marked preference for the oat manifested by *O. frit* in Europe, appeared to the writer to cast a strong doubt upon the identity of the American species; but after reviewing once more that phase of the subject he is of the opinion that there is no ground other than a physiological one for asserting that the species in North America is not *O. frit*. The case appears to resemble those mentioned by Dr. C. Gordon Hewitt (*11*) in his presidential address at the 1916 meeting of the American Association of Economic Entomologists, and others cited in the discussion of the address, in which strains of a species apparently arise which have a special adaptation to a certain food plant.

INFESTATION OF GRASSES

Much remains to be done in studying the relation of *Oscinis frit* to grasses. Only a few definite records of infestation exist, although most entomologists who have studied the insect assume that a considerable proportion of the flies, especially in middle and late summer, must breed in them. As already noted, sweepings made by the writer and by other entomologists who sent the material so obtained to him, show that from early summer onward the fly is much more abundant on bluegrass lawns than anywhere else. But sweepings on bluegrass that has begun to head or is in a later stage yield very few specimens, indicating that the presence of young shoots is the attraction. Sweepings on timothy in unmixed stand yield almost no specimens at any time, indicating that it is a plant unattractive to *O. frit*.

In 1915 five cages were prepared, each containing growing plants of wheat, bluegrass, and timothy. Several individuals of *Oscinis frit* of both sexes were placed in each. The only infestation that occurred was in wheat, from a stem of which a single maggot was taken and brought to maturity in a vial. From bluegrass sods placed in two cages no specimens of *O. frit* emerged, and several examinations of both stems and roots of the same grass gave no indications of infestation. *O. frit* has, however, been reared from this and other grasses, as the list of food plants will show.

KNOWN FOOD PLANTS

The following list of food plants includes those known for the United States and Canada. An asterisk (*) indicates that the fly was reared from this host by the writer. Numbers after authorities refer to the literature cited in this paper. The unpublished references are based on material identified by the writer.

*Wheat (stems). Garman (*10*), Fletcher (*8*), Webster (*21*), and Coquillett (*4*).
Wheat ("roots of wheat"). C. N. Ainslie, Moravia, Iowa (unpub.).
*Oats (stems). Webster (*21*), J. J. Davis, Sheldon, Ill. (unpub.).
*Oats (kernels).
*Barley.
*Emmer.
*Rye.
Corn (green cornstalks). Tucker (*20*).
*Timothy (*Phleum pratense*).
*Meadow fescue (*Festuca elatior*).
Kentucky bluegrass (*Poa pratensis*). Fletcher (*8*) and Webster (*18*).
Slender wheat-grass (*Agropyrum tenerum*). Fletcher (*8*).
Awned wheat-grass (*Agropyrum caninum*). Fletcher (*8*).
Quack grass (*Agropyrum repens*). Fletcher (*8*).
Rye grass (*Elymus canadensis*). Fletcher (*8*), and C. N. Ainslie, Elk Point, S. Dak. (unpub.).
Slough grass (*Spartina michauxiana*). C. N. Ainslie, Elk Point, S. Dak. (unpub.).
Barnyard grass (*Echinochloa crusgalli*). Webster (*21*) and C. N. Ainslie, Elk Point, S. Dak. (unpub.).
Low love-grass (*Eragrostis minor*). Webster (*21*).
Sedge (*Cyperus strigosus*). A. F. Satterthwait, La Fayette, Ind. (unpub.).
Cucumber roots. Webster (*21*).
Strawberry. Webster (*21*).
Ironweed (*Vernonia noveboracensis*). Wintering in seed capsules, Webster (*21*).

The last three records are the only ones on dicotyledons. It should be noted that the determinations were made at a time when the species of Oscinis were but little known, therefore they may be errors of identification or of observation.

PARASITES

Webster (*21, p. 56*) mentions having reared *Cyrtogaster occidentalis* Ashm. from either *Oscinis carbonaria*, *O. soror*, or *O. umbrosa* Loew, in Indiana. His uncertainty illustrates a common difficulty in rearing parasites from these forms. When material is taken from garden or field and placed in a cage to get the parasites, it is likely to contain the Hessianfly, Isosoma, Meromyza, Elachiptera, and several species of Oscinis. Although *Oscinis frit* may predominate, it is impossible to say positively that it was the host of the parasites. These are usually abundant. Even to isolate selected larvæ would not entirely obviate the difficulty, since at present no way is known to distinguish those of several species of oscinids. Parasitized larvæ would yield no adults, so there could not be a positive determination. Where cages are started by introducing adults on young wheat plants grown under cover, of course no parasitism is

possible; and this was the principal method used by the writer. Webster says:

Rhyssalus oscinidis Ashm. is parasitic on a species of Oscinis larvæ mining leaves of plantain at Washington;

but the miner referred to is now known to be *Agromyza melampyga* Loew, not Oscinis.

At present it can only be said that *Oscinis frit* appears to be freely parasitized by minute Hymenoptera, but observations have not as yet excluded all doubt in any case.

REMEDIES

The similarity of this insect's attack upon wheat to that of the Hessian fly indicates that a solution of the one trouble may carry the other with it. Unfortunately, the Hessian fly, although it has received a vast amount of attention, continues to inflict serious loss upon agriculture.

As far back as 1777, Bierkander (3) made recommendations for the control of *Oscinis frit* by changing the methods of tillage, and down to the present this is the only direction in which a lessening of its injury seems practicable.

Wheat sown early in the fall is more infested than that sown later, so the recommendation of late sowing to escape the Hessian fly will be equally applicable for *Oscinis frit*, but with this difference, that with the Hessian fly the possibility of infestation entirely ceases at a certain date, but with *O. frit* the chances decrease regularly until cold weather.

Wheat sown in the late spring is more infested than that sown early.

Continuous cropping in wheat appears to make no difference with the fly, which migrates freely for considerable distances.

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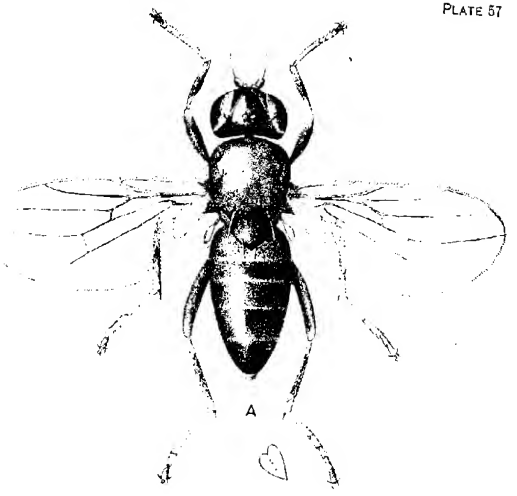
PLATE 57

Oscinis frit:

A.—Adult. × 35.
B.—Puparium. × 24.



A

B

LEPIDOPTERA AT LIGHT TRAPS

By W. B. TURNER, *Scientific Assistant, Cereal and Forage Insect Investigations, Bureau of Entomology, United States Department of Agriculture*

INTRODUCTION

In the summer of 1916 extensive observations were made at the Hagerstown (Md.) field station of the Bureau of Entomology for the purpose of obtaining additional information concerning the relative proportions of the sexes of moths taken at light traps. The results of these observations have been stated in a paper recently published.[1]

While the observations of 1916 were being carried on, it was hoped that opportunity would be found in the summer of 1917 for securing more minute data as to the night-flying habits of Lepidoptera. Various circumstances contributed to the defeat of the project in 1917, and in the summer of 1918 it was conducted under conditions even more restricted than in 1916.

It was impossible to devote every night to the work, and the compromise schedule of two nights each week was unavoidably interrupted by the absence of the writer on field duty and by the moving of the laboratory.

The work was carried on during the period from May 14 to September 13, so the proposed schedule of two nights each week would have embraced 36 observations. On account of the interruptions mentioned, only 28 nights were given to the work.

DESCRIPTION OF TRAP

The attracting light, with accessory cone of tin, was described in the paper to which reference has been made. The trap devised by the writer is illustrated in figure 1.

The trap was 12 by 14 inches at the base and 20 inches high, constructed of heavy galvanized iron. An opening 9 by 10 inches afforded access to the interior and was closed by a door 10 by 11 inches, the overlapping half inch on each margin being covered by strips of heavy felt cemented to the trap, so that the door was practically air-tight. The galvanized iron thimble supporting the glass tube which conveyed the acid to the cyanid was lined with felt, and the opening in the top to receive the cone was provided with a felt gasket. A ball of absorbent cotton tied in muslin and dropped into the cone further retarded the escape of the hydrocyanic-acid gas. A glass vessel with rounded bottom

[1] TURNER, W. B. FEMALE LEPIDOPTERA AT LIGHT TRAPS. *In* Jour. Agr. Research, v. 14, no. 3, p. 135–149. 1918. Literature cited, p. 148–149.

Journal of Agricultural Research,
Washington, D. C.

Vol. XVIII, No. 9
Feb. 2, 1920
Key No. K-82

held the charge of sodium cyanid and was provided with a wire-cloth cover having at its center a square of wood bored to receive the stem of a small glass funnel.' About five minutes were required to place the plug of cotton, pour the 25 per cent sulphuric acid into the glass tube, remove the dead moths, introduce a fresh charge of cyanid, and remove the tampon from the cone.

The trap was crated so that the door could be wedged tightly and the trap be made easy to handle.

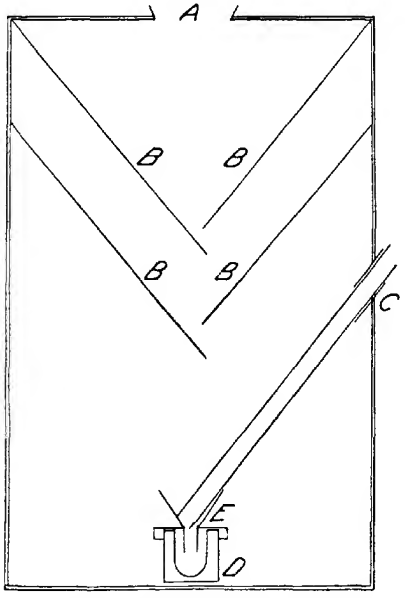


FIG. 1.—Light trap. A, opening for cone; BBBB, plates of glass; C, glass tube to convey acid; D, glass jar to hold cyanid; E, glass funnel.

RESULTS OF EXPERIMENTS

As has been stated, collections were made on 28 full nights between May 14 and September 13. The total of 3,152 moths recorded for that period embraces sixty-odd species. Of this total, 2,200, or 69.8 per cent, are males; and 952, or 30.2 per cent, are females. Table I gives an itemized account of the species, the numbers taken of each sex, and the percentage of males and females. In two species, *Noctua c-nigrum* and *Euparthenos nubilis*, the two sexes are equally represented; and of those species of which at least five individuals were taken, three show a preponderance of females.

TABLE I.—*Number and percentage of males and females of various species of Lepidoptera taken at a light trap, Hagerstown, Md., 1918*

Species.	Number of males.	Number of females.	Number of males and females.	Percentage of males.	Percentage of females.
Pholus pandorus	1	.....	1	100	.....
Phlegethontius 5-maculata	3	5	8	37.5	62.5
Darapsa myron	.....	1	1	.....	100
Darapsa pholus	1	.....	1	100	.....
Calasymbolus myops	1	.....	1	100	.....
Automeris io	1	.....	1	100	.....
Anisota rubicunda	2	.....	2	100	.....
Hypoprepia miniata	2	1	3	66.7	33.3
Utetheisa bella	.....	1	1	.....	100
Ectypantheria deflorata	.....	1	1	.....	100
Estigmene acraea	17	5	22	77.3	22.7
Hyphantria textor	118	13	131	90	10
Isia isabella	26	11	37	70.	30
Diacrisia virginica	43	3	46	93.5	6.5
Apantesis virgo	2	.....	2	100	.....
Apantesis persephone	.....	1	1	.....	100
Apantesis vittata	174	20	194	90	10
Euchaetias egle	7	.....	7	100	.....
Pareuchaetes tenera	1	2	3	33.3	66.7
Halisidota tessellaris	166	62	228	72.8	27.2
Alypia octomaculata	.....	1	1	.....	100
Arsilonche albovenosa	3	2	5	60	40
Polia renigera	45	58	103	43.7	56.3
Dipterygia scabriuscula	10	2	12	83.3	16.7
Prodenia commelinae	9	3	12	75	25
Prodenia ornithogalli	16	12	28	59	41
Agrotis ypsilon	55	21	76	72.4	27.6
Noctua c-nigrum	157	154	311	50.5	49.5
Feltia spp	228	123	351	65	35
Mamestra meditata	8	2	10	80	20
Mamestra picta	5	2	7	71.4	28.6
Mamestra adjuncta	5	2	7	71.4	28.6
Cirphis unipuncta	34	21	55	62	38
Cirphis phragmitidicola	207	97	304	73.3	26.6
Meliana diffusa	104	63	167	62.3	37.7
Papaipema nitela	2	.....	2	100	.....
Pyrrhia umbra	2	.....	2	100	.....
Cosmia paleacea	3	1	4	75	25
Rhodophora gaurae	1	.....	1	100	.....
Schinia marginata	9	17	26	35	65
Autographa biloba	5	1	6	83.3	16.7
Autographa brassicae	89	58	147	60.5	39.5
Autographa simplex	49	20	69	71	29
Chamyris cerintha	1	.....	1	100	.....
Tarache aprica	6	1	7	85.7	14.3
Caenurgia erechtea	301	94	395	76.2	23.8
Caenurgia crassiuscula	122	37	159	76.7	23.4
Catocala similis	.....	1	1	.....	100
Eupanthenes nubilis	3	3	6	50	50
Ypsia undularis	6	4	10	60	40
Datana ministra	22	5	27	80	20
Datana perspicua	2	.....	2	100	.....
Nadata gibbosa	1	.....	1	100	.....
Harpyia borealis	.....	1	1	.....	100
Cleora pampinaria	2	2	.....	100	.....
Xanthotype crocataria	1	.....	1	100	.....
Euchaud serrata	1	.....	1	100	.....
Azelina aneclaria	40	7	47	85	15

TABLE I.—*Number and percentage of males and females of various species of Lepidoptera taken at a light trap, Hagerstown, Md., 1918*—Continued

Species.	Number of males.	Number of females.	Number of males and females.	Percentage of males.	Percentage of females.
Tetracis crocallata		1	1		100
Harrisina americana	16		16	100	
Alteva aurea	5	12	17	30	70
Total	[a] 2,200	[b] 952	3,152		

[a] 69.8 per cent of total number of moths. [b] 30.2 per cent of total number of moths.

Table II gives the percentage of gravid females and shows that of 952 moths dissected, 736, or 77.3 per cent, were gravid, these constituting 23.35 per cent of all moths captured. Of the 11 genera of arctiids represented, all the females of 9 genera were gravid. Among the noctuids, gravid females made up 100 per cent in 8 genera.

TABLE II.—*Number and percentage of gravid female Lepidoptera taken at a light trap, Hagerstown, Md., 1918*

Species.	Number taken.	Number spent.	Number gravid.	Percentage gravid.
Phlegethontius 5-maculata	5		5	100
Darapsa myron	1		1	100
Hypoprepia miniata	1		1	100
Utetheisa bella	1		1	100
Ecpantheria deflorata	1	1		
Estigmene acraea	5		5	100
Hyphantria textor	13		13	100
Isia isabella	11	1	10	90
Diacrisia virginica	3		3	100
Apantesis persephone	1	1		
Apantesis vittata	20		20	100
Pareuchaetes tenera	2		2	100
Halisidota tessellaris	62	12	50	80.6
Alypia octomaculata	1		1	100
Arsilonche albovenosa	2		2	100
Polia renigera	58	12	46	80
Dipterygia scabriuscula	2		2	100
Prodenia commelinae	3	1	2	67
Prodenia ornithogalli	12	6	6	50
Agrotis ypsilon	21	6	15	71.4
Noctua c-nigrum	154	21	133	82.5
Feltia spp.	123	44	79	64.2
Mamestra meditata	2		2	100
Mamestra picta	2		2	100
Mamestra adjuncta	2		2	100
Cirphis unipuncta	21	8	13	62
Cirphis phragmitidicola	97	13	84	86.6
Meliana diffusa	63	20	43	68
Cosmia paleacea	1	1		
Schinia marginata	17	3	14	82.4
Autographa biloba	1	1		
Autographa brassicae	58	17	41	70
Autographa simplex	20	2	18	90

TABLE II.—*Number and percentage of gravid female Lepidoptera taken at a light trap, Hagerstown, Md., 1918*—Continued

Species.	Number taken.	Number spent.	Number gravid.	Percentage gravid.
Tarache aprica	1	.....	1	100
Caenurgia erechtea	94	31	63	67
Caenurgia crassiuscula	37	10	27	73
Catocala similis	1	1	.....	.....
Euparthenos nubilis	3	1	2	67
Ypsia undularis	4	.....	4	100
Harpyia borealis	1	.....	1	100
Datana ministra	5	.....	5	100
Aselina ancetaria	7	1	6	85.9
Tetracis crocallata	1	.....	1	100
Atteva aurea	12	2	10	83.3
Total	952	216	[a] 736	.....

[a] 77.3 per cent of total number of females.

TABLE III.—*Meteorological data, arranged by dates and hours of collections*

Date.	Temperature.		Humidity.		Time of flight.	Number of males and females.	Males.		Females.		Remarks.
	Max.	Min.	Max.	Min.			Number.	Per cent.	Number.	Per cent.	
1918.	°F.	°F.	P. ct.	P. ct.							
May 14–15					7 p. m.–1 a. m.	61	47	75.8	15	24.2	Electric current failed 1.05 a. m.
17–18					8 p. m.–4 a. m.	59	45	81.3	11	18.7	
21–22					7 p. m.–4 a. m.	60	55	91.7	5	8.3	Heavy fog 12 p. m. to 4 a. m.
24–25					do	24	16	66.6	8	33.4	Drizzling rain during entire period.
28–29					7 p. m.–12 p. m.	85	58	68.2	27	31.8	Material taken between 12 p. m. and 4 a. m. destroyed.
31											
June 1	88	72	78	70	7 p. m.–1 a. m.	512	366	71.5	146	28.5	
14–15	70	55	95	85	7 p. m.–4 a. m.	262	232	88.4	30	11.5	Heavy fog 2 a. m. to 4 a. m.
18–19	73	58	78	60	do	262	202	77.1	60	22.9	
21–22	63	54	88	87	4 p. m.–4 a. m.	33	25	75.4	10	28.9	Rain 7 p. m. to 3 a. m.
July 9–10					8 p. m.–4 a. m.	47	34	72.3	13	27.7	
12–13					do	52	35	67.3	17	32.7	
16–17					do	81	62	76.5	19	23.5	
19–20					do	63	50	80	13	20	
23–24					do	29	22	76	7	24	
26–27	85	72	89	68	do	50	36	90	4	10	
30–31					do	48	40	83.3	8	16.7	
Aug. 2–3	83	70	91	74	do	73	44	60	29	40	
6–7	98	95	89	87	do	232	151	65	81	35	
9–10	80	74	85	74	do	177	125	70.6	52	29.4	
13–14	75	71	85	83	do	101	59	58.4	42	41.6	
20–21	76	55	89	75	do	83	54	65	29	35	
23–24	90	75	81	70	do	88	47	53.4	41	46.6	
27–28	75	70	90	85	do	157	94	60	63	40	
30–31	69	65	88	83	do	125	94	75.2	31	24.8	
Sept. 3–4	75	63	87	83	do	259	171	66.1	88	33.9	
6–7	65	58	72	06	do	87	55	63.2	32	36.8	
10–11	75	65	68	03	do	110	67	57.8	49	42.2	
13–14	65	60	78	48	do	42	31	74	11	26	
Total						3,152	[a] 2,200		[b] 952		

[a] 69.8 per cent of total number of moths. [b] 30.2 per cent of total number of moths.

Partial records of temperature and humidity are given in Table III. It is believed from the somewhat scanty data that the night-flying habits of moths are but little influenced by these factors. On the other hand, such meteorological conditions as strong winds, rain, or fog materially restrict flight.

Data as to the total collection of moths, arranged by hours of collection, are set forth in Tables IV and V.

TABLE IV.—*Numbers and percentages of males and of gravid and spent females arranged by periods of collection*

Period ending—	Number of males and females.	Males.		Gravid females.		Spent females.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
8 p. m.	23	15	65.2	7	30.4	1	4.4
9 p. m.	354	194	54.8	143	40.4	17	4.8
10 p. m.	372	215	57.8	145	39	12	3.2
11 p. m.	438	331	75.6	88	20	19	4.4
12 p. m.	375	265	70.6	82	22	28	7.4
1 a. m.	391	288	73.6	78	20	25	6.4
2 a. m.	482	365	75.7	75	15.6	42	8.7
3 a. m.	407	307	75.3	63	15.6	37	9.1
4 a. m.	310	220	71	55	17.7	35	11.3
Total	3,150	[a]2,200	.....	[b]736	.....	[c]216	.....

[a] 69.8 per cent of total number of moths.
[b] 23.35 per cent of total number of moths.
[c] 6.85 per cent of total number of moths.

TABLE V.—*Summarized data, arranged by periods of collection*

Period ending—	All moths.				Males.				Females.			
	Number in each period.	Percentage of total number.	Accumulated number at end of each period.	Percentage of total number.	Number in each period.	Percentage of total number.	Accumulated number at end of each period.	Percentage of total number.	Number in each period.	Percentage of total number.	Accumulated number at end of each period.	Percentage of total number.
8 p. m.	23	0.7	23	0.7	15	0.7	15	0.7	8	0.8	8	0.8
9 p. m.	354	11.2	377	11.9	194	8.8	209	9.5	160	17.0	168	17.8
10 p. m.	372	11.8	749	23.7	215	9.8	424	19.3	157	17.0	325	34.8
11 p. m.	438	14.0	1,187	37.7	331	15.0	755	34.3	107	11.2	432	46.0
12 p. m.	375	11.9	1,562	49.6	265	12.0	1,020	46.3	110	11.3	542	57.3
1 a. m.	391	12.4	1,953	62.0	288	13.1	1,308	59.4	103	11.2	645	68.5
2 a. m.	482	15.3	2,435	77.3	365	16.6	1,673	76.0	117	12.3	762	80.8
3 a. m.	407	12.9	2,842	90.2	307	14.0	1,980	90.0	100	10.1	862	90.9
4 a. m.	310	9.8	3,152	100.0	220	10.0	2,200	100.0	90	9.1	952	100.0
Total	3,152	.....	.....	.....	[a]2,200	.....	.....	.....	[b]952	.....	.....	.....

[a] 69.8 per cent of total number of moths.
[b] 30.2 per cent of total number of moths.

It will be seen from these tables that in the first three periods, ending at 10 p. m., there were taken 325 females, or 35 per cent of the total of 952 females and 40 per cent of the total of gravid females. In the same

period, 424 males, or 19 per cent of the total of males, were killed. From 10 p. m. to 4 a. m. the percentage of gravid females declined while that of males and spent females increased. These figures agree with the deductions made by Mr. Geo. G. Ainslie in the excellent paper, "Crambid Moths and Light,"[1] in that a larger percentage of the total number of gravid females and a smaller percentage of the total number of males were captured during the early hours of the night.

That the percentages given here do not approximate more closely those for the material collected at Nashville, Tenn., during the summer of 1915 can be readily understood when it is remembered that Mr. Ainslie's collections were made up practically of one species, *Crambus teterrellus* Zicken, which, as he writes, "is a species without distinct generations and the moths are quite uniformly abundant" during the seasonal period of the adults. The collections made at Hagerstown in the summer of 1918 embraced some sixty-odd species, representing 10 families. Of these 60 species, at least 20 are of economic importance; and several others are likely to prove serious pests if circumstances favor them.

[1] AINSLIE, GEO. G. CRAMBID MOTHS AND LIGHT. In Jour. Econ. Ent., v. 10, no. 2, p. 114-123, 3 fig. 1917.

LIFE HISTORY OF EUBIOMYIA CALOSOMAE, A TACHINID PARASITE OF CALOSOMA BEETLES

By C. W. COLLINS, *Entomological Assistant*, and CLIFFORD E. HOOD, *Scientific Assistant, Gipsy Moth and Brown-tail Moth Investigations, Bureau of Entomology, United States Department of Agriculture*

INTRODUCTION [1]

In May, 1906, the first adult colony of *Calosoma sycophanta* L. from Europe was liberated in Saugus, Mass. Importations were continued to the close of 1910, and colonizations were made from the material received. During this period rearings were made from the foreign parents, and colonizations were made with the larvæ. During 1912, adults collected in the field for breeding experiments at Melrose Highlands, Mass., died, and from them issued several specimens of a tachinid parasite now known as *Eubiomyia calosomae* Coq. This was the first indication of tachinid parasites from foreign or native material attacking *C. sycophanta* since the introduction of the beetles in 1906, although many beetles arriving dead from Zurich, Switzerland, were placed in tight containers for the purpose of determining whether they were parasitized. No parasites were reared from any foreign material.

The parasite was again recovered from native adults of *Calosoma sycophanta* in 1914. Its importance as a parasite of this economic predacious species was realized, and investigations were begun the following year to secure biological data on the species in order to determine its present and possible future effect on the beetles.

In 1896 Burgess (*2*) [2] collected an adult specimen of *Calosoma calidum* Fab. in Malden, Mass. (although the literature does not give this locality), from which were reared seven flies. These specimens were forwarded to the Bureau of Entomology from Amherst, Mass., and were erroneously labeled and recorded as from that locality. They were determined by Coquillett (*2*) as *Pseudatractocera calosomae* Coq. He stated further that he had bred the same species from *C. peregrinator* Guer. in California. In 1891 Brauer and Bergenstamm (*1*) described a tachinid sent them from the State of Georgia as *Viviania georgiae* B. and B., which they regarded as a distinct species. This form is closely allied to *V. cinerea* Fall., a

[1] The writers are indebted to Dr. L. O. Howard for the loan of specimens from the United States National Museum for comparison; to A. F. Burgess for valuable suggestions in obtaining notes on the life history of the species; to the late Frederick Knab, of the United States National Museum; to C. W. Johnson, of the Boston Society of Natural History, and to R. T. Webber, of the Bureau of Entomology, for comparison and determination of material; and to various men of this bureau stationed at the Gipsy Moth Laboratory, Melrose Highlands, Mass., for collection of beetles yielding parasites.

[2] Reference is made by number (italic) to "Literature cited," p. 497.

Journal of Agricultural Research,
Washington, D. C.
to

Vol. XVIII, No. 9
Feb. 2, 1920
Key No. K-83

species bred from Carabus in Europe. Coquillett, referring to the same specimens determined as *P. calosomae* in 1896, included them in 1897 (*5, p. 82*) as *Biomyia georgiae* B. and B.

Tothill in 1913 (*7*) and Burgess and Collins in 1915 (*3, p. 19*) and 1917 (*4, p. 11-12*) recorded rearings of this parasite from *Calosoma sycophanta* under the name of *Biomyia* or *Viviania georgiae* B. and B. A footnote was added by the latter writers to the effect that Dr. C. H. T. Townsend had recently described this species as belonging to a new genus, Eubiomyia, genotype *Pseudatractocera calosomae* Coq. Dr. Townsend's description appeared in 1916 (*8, p. 74*) under this name. Mr. R. T. Webber, of this bureau, has carefully compared specimens bred by the writers at Melrose Highlands, Mass., with the cotype of the above species from the United States National Museum and declares them identical, hence this name is applied to the parasite treated in this paper.

DESCRIPTION OF THE PARASITE

ADULT

The description of *Eubiomyia calosomae* Coq. (Pl. 59, D) as published by Dr. C. H. T. Townsend is included verbatim:

Eubiomyia, new genus.

Genotype, *Pseudatractocera calosomæ* Coqt., 1897, Rev. Tach. 82, resurrected name for *Biomyia* (*Viviania*) *georgiae* Coqt., 1897, l. c., pp., Amherst, Massachusetts (not *Viviania georgiae* B. B.) Holotype, No. 20202 U. S. Nat. Mus., male, reared by A. F. Burgess from adult *Calosoma calidum* at Amherst, Massachusetts.[1]

Differs from *Biomyia* as follows: Female vertex about one-half eye-width. Parafacials, parafrontals, and frontalia all much narrower. Antennæ not so elongate, more narrowed; third joint in both sexes about twice as long as second joint. Frontoorbital bristles closely crowded against frontal bristles. Face more receding, the lower border of head much shorter. Front in both sexes nearly same width. Female without discal macrochætæ on intermediate abdominal segments, male with small ones. Metatarsi of male swollen, especially hind ones, agreeing in this character with *Pseudatractocera*. Apical cell closed, costal spine rather small.

Differs from *Pseudatractocera* as follows: Epistoma shorter and broader. Front less prominent. Parafacials narrower, bare. Hind crossvein nearly in middle between small crossvein and bend of fourth vein. Also in frontal and discal-macrochæta characters given above.

It may be noted here that *Viviania georgiae* B. B. is a *Pseudatractocera*.

The following descriptions of the egg, larva, and pupa of *Eubiomyia calosomae* are by the writers.

EGG

Egg (Pl. 58, A) elongate oval, tapering slightly toward the posterior end. Cylindrical in form from above but flat on lower surface, which is glued to beetle in process of deposition, lower surface being covered with a thin membrane. Color pale yellowish white. Specimens preserved in alcohol and mounted in balsam measured from 0.61 mm. long and 0.34 mm. broad to 0.75 mm. long and 0.4 mm. broad, or an average of 0.68 mm. long and 0.36 mm. broad.

[1] This specimen with others was forwarded to the Bureau of Entomology from Amherst, Mass., but was reared from an adult *Calosoma calidum* collected in Malden, Mass.

The eggs are almost fully developed at the period of deposition, and hatch ordinarily in less than 24 hours. In two instances, one on July 31 and the other on August 1, the eggs were deposited and hatched within 3 hours or less. This is the shortest time recorded. On August 5, 1917, an instance was noted where an egg was deposited, hatched, and the larva had entered its host in less than 13 hours. On August 5 at 9.30 a. m. one egg was observed on a beetle and was removed from its host 24 hours later, still unhatched.

The embryo during hatching makes its way out of the chorion through a small hole (Pl. 58, A) made in the thin membrane on the ventral side. This exit hole is near the anterior end of the egg, the extremity at which the larva emerges from beneath. Fertile eggs in any stage of development if removed from the exoskeleton of the beetles always fail to hatch. This results probably from the immediate drying of the membrane when exposed to the air or the lack of the exoskeleton of the beetle as a base for the embryo to press against in forcing an exit.

LARVA

FIRST INSTAR

One larva less than a day old, dissected from a beetle, measured 2 mm. long and 0.82 mm. broad. Another larva 2 days old measured 2.5 mm. long and 1 mm. broad. Color white. Form elongate, broadest across eighth and ninth segments, tapering gradually towards anterior end. The segments are provided with irregular annular rows of minute black spines which are very indistinct in this stage. Young larva inclosed in a thin, white, membranous encasement or funnel, formed apparently by the growth from the injured or punctured tracheal branch to which it is attached. Funnel soon changes to brown upon exposure to light.

The small larvæ enter their host immediately after hatching, probably through the spiracles. A dissection, August 5 at 2 p. m., of an adult *Calosoma sycophanta* which contained one egg of *Eubiomyia calosomae* deposited in late afternoon or early evening of August 4 revealed a small maggot inclosed in a "funnel" attached to the tracheæ in the region of the metathorax. The anal stigmata of the larva protruded into a hole forced through the wall of the tracheal branch. The spiracles of *C. sycophanta* are composed of an elongate chitinous ring, the inner margin of which is thickly clothed with short hairs directed towards the center. The spiracles measure from 0.8 to 0.9 mm. long and 0.3 to 0.37 mm. broad. In a laboratory experiment, an egg of *E. calosomae* was easily forced into the aperture made by pressing the spiracle open. This leads to the supposition that the young larva enters in this way. Some other laboratory experiments were tried which also tend to strengthen this point. Several partly developed third-instar larvæ were transferred from a parasitized beetle to a normal living specimen. This was accomplished by making an incision in the dorsum of the abdomen of the second beetle and inserting the larva, the wound soon healing. The body of a

normal, well-fed Calosoma is usually quite full of blood, in contrast to the body of a parasitized specimen containing third-instar larvæ. Nevertheless the transferred immature larvæ all died, while the beetles sometimes lived more than a month. These larvæ, though they move about freely in the body cavity of a parasitized beetle where the blood and fats have been greatly reduced, can not withstand the sudden change to full-blooded conditions as found in normal specimens. It is probable that they died from drowning or suffocation.

SECOND OR HIBERNATING INSTAR (PL. 58, D)

Specimens preserved in alcohol ranged from 4.8 mm. long and 1.9 mm. broad to 5.1 mm. long and 2.2 mm. broad, or an average of 4.9 mm. long and 2.1 mm. broad. Color white, form elongate. Larva inclosed in light-brownish tracheal "funnel" which darkens on exposure to light. Funnel of thin membranous tissue darker and thicker at anal end. Base of funnel constricted where it joins walls of trachea and sometimes angled at point of constriction.

The parasite passes the hibernation period as a half-grown or second-instar larva. It remains attached to the tracheal branches of the metathorax in the same position as in the first instar. During July and early August the adults of *Calosoma sycophanta* begin to enter the earth for hibernation, and some of them contain the first-instar larva of the parasite; this larva transforms to the second instar and then ceases its activity and feeding and becomes dormant soon after the beetle has constructed a cavity. Activity of the host and that of its parasite are resumed almost simultaneously in the spring. With parasitized specimens of *C. sycophanta* this activity usually occurs in the latter part of May and the first of June.

THIRD INSTAR (PL. 58, C)

Color grayish white. Varying in size from 8 mm. long and 3 mm. broad to 9.5 mm. long and 3.5 mm. broad, or an average for six alcoholic specimens of 9 mm. long and 3.3 mm. broad. Larva broadest across the eighth or ninth segment, tapering gradually toward anterior and more noticeably toward the posterior end. Each segment except the head is provided with annular spine areas composed of many broken rows of very short black spines, ranging from 6 to 18 rows in each area. These spine areas cover about half the area of the segment, the remaining portion being smooth. Mouth hook (Pl. 58, B) partly visible, especially the two sharp, curved extremities. Anal stigmata rather widely separated in well-fed larvæ. Inner margins almost parallel, rounding at dorsal, ventral, and lateral extremities. Each stigma containing six radial elongate slits. Outer margins of stigmata brownish black and central areas light brown. Stigmata arising out of depression in the anal segment. Larva not found inclosed in tracheal funnel in this stage, as in first and second stages.

When the larvæ have reached the third instar they are found, upon dissection of the host, in all parts of the body cavity from the prothorax to the tip of the abdomen. After the greater portion of blood and fats has been reduced as a result of the constant feeding of several larvæ, the latter move about freely in the body cavity. Their movements increase as the host weakens and approaches death. Feeding and activ-

ity of the larvæ within the body cavity sometimes extend over a period of one or more days after death of the host, which has been hastened by dissection.

The time required for the development of the larva from the hatching of the egg to pupation ranges from 9 to 12 days during midsummer. On June 23, 1917, Mr. F. W. Graham, of this bureau, collected an adult of *Calosoma sycophanta* in the field bearing two eggs of the parasite. By June 24, the chorion of the eggs had disappeared. On July 16 two flies issued. Allowing 11 days for passing the pupal stage, 12 days must have been required to pass the larval instars. In another instance a beetle containing eggs of the parasite was collected in the field, and a dissection of one of the eggs revealed an embryo. The same beetle contained puparia 10 days later. Other breeding records indicate that from 10 to 12 days are passed in the larval stages for the summer generations.

PUPARIUM (PL. 59, A)

Color reddish brown, form elongate, surface smooth when viewed with naked eye but with aid of lens showing 6 to 18 broken annular rows composed of short, thick-set spines to be seen on each segment (Pl. 59, C). These rows appear as continuous, wavy, broken lines, except with high power lens in which case the spines appear distinct but very closely set. Spine area sometimes covering one-half the surface of the segments, but more prominent on anterior and posterior segments. Anal stigmata (Pl. 59, B) protruding above surface of puparium, inner margins almost parallel, and each containing six radiating elongate slits. Puparia ranging in size from 5 mm. long and 2.2 mm. broad to 8 2 mm. long and 4 mm. broad, or an average for eight specimens of 6.6 mm. long and 3.1 mm. broad.

The full-grown larva soon after accomplishing the killing of its host enters the pupal stage. Some of the larvæ in a host containing any number of parasites up to 15 force a hole between the abdominal tergites laterad and pupate just beneath or between the wings and elytra. Of 620 puparia under observation in 1915, 245, or 40 per cent, pupated within the body cavity and 375, or 60 per cent, between the dorsum of the abdomen and the elytra. The maggot pupates very shortly after the death of its host, the period being hastened somewhat where dissections are made which expose the tissue of the host and the maggot to the drying of the air. When the host is opened and contains maggots practically full grown, pupation usually follows in from 10 to 36 hours.

The time passed in the pupal stage ranges from 9 to 15 days. An average of 12 days in midsummer was required in 1915 by many specimens under observation; 11½ days were required in 1916 and 11 days in 1917.

DISTRIBUTION OF THE PARASITE

Eubiomyia calosomae has been bred from collections of *Calosoma sycophanta* from many towns in eastern Massachusetts and from one or more towns in Maine, New Hampshire, and Rhode Island. Its known

distribution occurs as far north as York County, Me.; Merrimack County, N. H.; as far west as Worcester County, Mass.; and as far south as Plymouth County, Mass., and Providence County, R. I. It undoubtedly occurs in New England outside these limits, for the distribution of *C. sycophanta* extends beyond the above-named localities and into Connecticut. It has been bred also from *C. frigidum* Kirby and *C. calidum* Fab., which were collected within the above-named limits. Since the two latter species occur as far south as Georgia and Texas and as far west and north as Nebraska, North Dakota, and Canada, the parasite is likely to be found in any part of this extensive territory.

It was first thought when this species was bred from *Calosoma sycophanta* in 1912 and 1914 that it might be *Viviania cinerea* Fall. of Europe, introduced from that continent with the beetles during the years 1905 to 1910. The first shipment of beetles was received from the late Dr. G. Leonardi, of Portici, Italy. Practically all later shipments were sent by Miss Marie Ruhl, Zurich, Switzerland. These were shipped in tight boxes, and when these were opened on this side the specimens and packing material were examined for parasites. In most instances the dead adults were inclosed in a jar containing earth in order to rear any possible parasites. The table shows that 4,046 living specimens and 2,097 dead specimens of *C. sycophanta* were received from Europe and no signs of parasites were observed. It might be added that 348 adults received between 1905 and 1910, and pinned at that time, were later dissected with negative results.

The data at hand tend to point to the fact that the species was not introduced from Europe but is native to New England, being first bred by A. F. Burgess in 1897 from *Calosoma calidum* and later found more abundantly in *C. sycophanta*.

TABLE I.—*Number of living and dead specimens of Calosoma sycophanta received from Europe*

Year.	Living.	Dead.
1905	1	215
1906	693	128
1907	967	1,125
1908	675	113
1909	405	39
1910	1,305	477
Total	4,046	2,097

EQUIPMENT USED IN BREEDING EXPERIMENTS

During 1915, when the first extensive breeding experiments were begun, the flies issuing from the parasitized beetles were inclosed in small wooden, glass-covered trays 12 by 12 by 3¼ inches with a bottom

upon which earth was placed. Two or more specimens of Calosoma were inclosed with some caterpillars for food. The flies were offered sugar and water absorbed in a sponge and also sprayed on foliage. About 372 flies were used in the experiments, but no copulation or oviposition was observed that year.

In 1916, although fewer flies were reared than in 1915, a show case was modified so as to answer for a breeding cage. It measured 31½ by 21½ inches and was 11 inches deep. The glass was removed from the ends and fly screen substituted. The top and one side were of glass, and the other side contained two sliding doors. Shallow pans of earth were inclosed for the beetles, and flowers and sweetened water for the flies. More freedom was given the host and its parasites, and better results attended these efforts. Fertile eggs were secured in 1916, 1917, and 1918.

The beetles parasitized in the breeding cage were transferred to large glass battery jars partly filled with loam for hibernation and also to box cages set in the ground. These cages were provided with a top and bottom of copper wire of fine mesh.

PARASITES BRED FROM FIELD COLLECTIONS OF CALOSOMA SYCOPHANTA

During the seasons of 1915, 1916, 1917, and 1918 large field collections of beetles were made in eastern Massachusetts where the species had become abundant. These collections were made for the dual purpose of securing specimens for colonization in new and outside territory infested with *Porthetria dispar* and of studying the parasite attacking them. During 1915, 15,322 beetles were collected, and 204, or 1.3 per cent, died of parasitism. At that time such large numbers were collected for colonization that it was impracticable to hold all of them in cages until all died that would have succumbed to parasitism, hence the percentage is probably slightly lower than it normally should be. During 1916, 465 beetles were collected. These were fed in cages long enough for all those affected with parasites to have died. Sixteen beetles, or 3.4 per cent, died from parasitism. During 1917, 4,679 beetles were collected and confined in large cages. Sixty-three of these, or 1.3 per cent, died from parasitism. Six hundred of this lot were forwarded to Mr. L. S. McLaine, of the Department of Agriculture, Dominion of Canada, located at Frederickton, New Brunswick, for colonization. Mr. McLaine, upon request, held and fed the beetles in cages until July 21. During this period 20 died, and 18 flies issued from the 20 dead. This would indicate that from 6 to 10 died of parasitism, since an average of about 3 flies usually issue from each beetle. A total of 6,072 beetles were collected in 1918, and only 16, or 0.26 per cent, died from parasitism.

During these years the dead beetles collected in the field or dying in the cages at the laboratory were dissected or isolated in vials or jars for issuance of the parasites. The data collected in 1915 showed that the

204 parasitized beetles collected contained 763 puparia, from which 641 flies issued, 122 dying in the pupal stage. The highest number of puparia contained in one beetle was 16 and the lowest 1. This gives an average of 3.7 puparia in each parasitized beetle, from which an average of 3 flies issued. The data secured in 1916 showed an average of 3 puparia per beetle, from which an average of 2.8 flies issued.

All adults of *Calosoma sycophanta* collected in the field for colonization purposes in 1917 and 1918 were examined individually for eggs of the parasite as soon as they arrived at the laboratory. Although the eggs hatch in a short time, the chorion sometimes remains glued to the beetles for a few days. A total of 5,707 adults were collected in 1917 between June 20 and July 24. Five beetles were found containing eggs of the parasite on the following dates: June 23, June 25, and July 6. During 1918, 6,072 adults were collected in the field between May 28 and July 19. Two beetles containing eggs were collected on June 5 and July 3. Those eggs found on June 5 apparently were deposited by flies of the winter generation and those of July 3 by flies of the summer generation.

PARASITES BRED FROM FIELD COLLECTIONS OF CALOSOMA CALIDUM FAB., CALOSOMA FRIGIDUM KIRBY, AND CARABUS NEMORALIS MÜLL., 1912–1918

Small collections of adults of *Calosoma calidum* Fab., *Calosoma frigidum* Kirby, and *Carabus nemoralis* Müll. were made almost every year in eastern Massachusetts and southern New Hampshire between 1912 and 1918 and confined in jars of earth at the laboratory. From them specimens of *Eubiomyia calosomae* were bred occasionally. Since some of the early rearings from these collections were more or less accidental, it is thought advisable to give the percentage of parasitism as based on the total collections of each species for the 7-year period. During this period 92 specimens of *Calosoma calidum* were collected, 3 specimens, or 3.3 per cent, of which were parasitized. A total of 238 adults of *Calosoma frigidum* were collected, of which but 1, or 0.42 per cent, yielded parasites; and 169 adults of *Carabus nemoralis* were collected, 1 of which, or 0.59 per cent, was parasitized. It might be added that in 1912 when 49 adults of *Calosoma calidum* were collected, 3, or 6 per cent, yielded to parasitism and in 1915, when only 3 adults of the same species were collected, 1, or 33 per cent, later died of parasites.

These records tend to indicate that the parasite is slightly more effective on *Calosoma calidum* than on *C. sycophanta*. This may explain in part why the former species is less common in New England than formerly.

LIFE-HISTORY STUDIES

OVIPOSITION

The eggs are deposited by the female on the exterior surface of Calosoma adults, being glued to several parts of the exoskeleton. They are deposited singly and in patches of 2, 3, and 4. Eggs have been found attached to

elytra, dorsum and lateral portions of prothorax, ventral portion of abdomen, and femora of *Calosoma sycophanta*.

During the season of 1916, summer generation flies in cages deposited 95 eggs on 38 beetles, and in 1917, they deposited 177 eggs on 68 beetles, or an average of more than 2 per beetle for each season. Of those deposited in 1917, 61 eggs were found on the abdomens, 52 on the prothoraces, 20 on the metathoraces, and scattering ones on the legs and elytra of the various beetles. The largest numbers deposited on one beetle in the breeding experiments were 10 and 9 during 1916 and 1917, respectively.

The period of oviposition in the cage experiments was from July 28 to August 16 in 1916, from July 22 to August 12 in 1917, and from July 19 to July 27 in 1918.

The flies in the breeding cages are most active during the late afternoon and early morning—the times at which adults of Calosoma are least active. Oviposition was observed in a cage on August 6, 1915, at 5.50 a. m. and at 6.35 a. m. The flies were observed to run after the beetles as early as 4 a. m.—the breaking of day. Eggs have also been found deposited on beetles between 5 p. m. and dusk. The female fly lights near the beetle and mounts upon the dorsum of its host either by crawling upon it or by a short flight. The beetles in cages sometimes show little disturbance from the presence of the parasites near or upon them. Occasionally they are seen to run slowly away from the active flies.

COPULATION

Attempts were made to observe copulation of this species at various periods during the season in 1915 and 1916. Pairs of flies were inclosed in lamp chimneys and glass jars and provided with foliage and a sugar solution. Observations were made frequently, the flies being separated at night and returned to the receptacle each day, but negative results attended these efforts until 1917.

On July 21, 1917, one male and three female flies issued in a vial. The male, which was less than 24 hours old, was transferred to a vial containing another female of the same age. Copulation ensued within two minutes, continuing for a period of six minutes, whereupon the pair was transferred to the large breeding cage with other specimens. After this period many fertile eggs were secured during the progress of the experiment.

LONGEVITY

On July 10, 1915, two males and two females, newly issued specimens, were inclosed in a wooden tray with glass cover to obtain data on the longevity of the species. Foliage and cotton saturated with sugar solution were also supplied in the tray. The length of life was as follows: One

male lived 4 days, one male 5 days, one female 9 days, and one female 16 days.

Another similar experiment was started on July 14, 1915, with eight flies inclosed in a lamp chimney. The length of life was as follows: One fly lived 7 days, one fly 8 days, two flies 11 days, one fly 23 days, one fly 24 days, one fly 26 days, and one fly 30 days. The minimum in this experiment was 7 days and the maximum 30 days, or an average of 18.

HIBERNATION

Eubiomyia calosomae hibernates in the second larval instar (Pl. 58, D) within the body cavity of Calosoma adults. The small maggot, after hatching, enters the body probably through the spiracles, for the first-instar larva is found attached to the tracheal branches in the metathoracic region. It feeds in this location for a few days and enters the second instar about the time the beetles enter the earth for hibernation.

Four eggs were deposited upon an adult in the breeding cage on July 26, 1917, and the beetle was immediately transferred to a jar of earth into which it descended for hibernation about August 1. The beetle was dissected February 9, 1918, and was found to contain four second-instar larvæ securely attached posteriorly to the tracheal system of the beetle and inclosed in a tracheal funnel. The location of these larvæ was within the body cavity above the metasternum and lying longitudinally with the anal stigmata pointing toward the anterior end of the beetle.

When spring arrives the parasitized beetles, pressed by weakness from loss of blood and fats, begin early in the season to wend their way upward to the surface of the ground in search of food. The parasites are probably feeding all the while during this activity, further weakening their host; and death results in the course of two or three days. The dead parasitized beetles are usually found on the surface of the earth. It is quite probable that they sometimes die before wholly emerging, but it has been proved by laboratory experiments that flies issuing under such conditions are capable of forcing their way through a few inches of earth without harm to themselves.

The parasitized beetles emerged on May 25, 1916, and about June 1, 1917; but the maximum normal field emergence of specimens of *Calosoma sycophanta* was about June 10 to 15 during those years.

NUMBER OF GENERATIONS AND PERIOD OF EMERGENCE OF FLIES

Eubiomyia calosomae passes through two complete generations a year on *Calosoma sycophanta* as a host and in some instances, where beetles remain active for a period of one week or more after becoming parasitized, through a partial third generation. On May 27, 1915, H. W. Allen collected a female of *Eubiomyia calosomae* at Lunenburg, Mass. This is the earliest known seasonal record of issuance of adults in the

field. From adults of *C. sycophanta* collected in the field in late July, 1915, and allowed to hibernate in large cages the following winter, one parasitized female emerged on May 25. On May 26 it was dead, and when dissected contained a puparium. The fly issued June 6, 1916. Between August 4 and 10, 1916, eggs were deposited upon two beetles and the latter allowed to hibernate in ground cages. On June 5, 1917, the two beetles were found dead on the surface of the earth from which they had recently emerged, Each contained one puparium. One fly issued from these on June 9, 1917. The flies mentioned above were of the winter generation, or parent stock of the summer generation or generations. The first issuance of the summer generation from parasitized adults of *C. sycophanta* from field collections was on July 6, 1915, July 10, 1916, and July 11, 1917. The corresponding last dates of issuance for these years were August 21 for 1915, July 28 for 1916, August 3 for 1917, and as late as August 21 in a reproduction experiment in 1917. These dates differed both because of variation in the number of parasitized beetles collected each year and because of variation in the seasons.

Three female specimens of *Calosoma sycophanta* were parasitized in a breeding cage late on July 26 or early on July 27, 1917, and were transferred to jars of earth for hibernation. The first female soon entered the earth, making its cavity 5 inches below the surface. The other two females remained active on the surface of earth in the jar and fed for about a week. On August 4 the first beetle was removed from its cavity, killed, dissected, and found to contain two second-stage or dormant hibernating maggots. The second and third females were found dead on the surface of the earth in the jar on August 4 and 7, respectively. These latter beetles contained active third-stage maggots from which eight flies issued between August 15 and 21. Similar records were secured in 1918. Most of the flies issuing in the field after July 20 to 25 probably perish for lack of a suitable host in a species of Calosoma, since practically all the adults of the latter have entered the earth for hibernation by this time. Presumably the first issuing flies of the summer generation oviposit upon beetles, from which, if they remain active for a sufficient period, there later issue flies of the second summer generation.

Table II shows the daily issuance of flies for three seasons. It will be observed that the maximum issuance of flies during average seasons occurred between July 6 and August 1. Adults of *Calosoma sycophanta* are most abundant in the field from June 15 to July 10, decreasing in abundance very rapidly after the latter date. Active beetles are very rarely met in the field after August 1, hence the late issuing flies find a great scarcity of hosts upon which to oviposit. This in turn accounts for the low percentage of parasitism generally found among the beetles emerging from hibernation in late May and June.

TABLE II.—*Number of parasites issuing and dates of emergence from adults of Calosoma sycophanta, 1915, 1916, and 1917*

Date.	Number of parasites issued daily.			Generation.
	1915.	1916.	1917.	
June 6	.....	1	.....	Winter.
9	.....	.....	1	Do.
July 6	6	.....	.....	Summer.
7	5	.....	.....	Do.
8	19	.....	.....	Do.
9	10	.....	.....	Do.
10	9	2	.....	Do.
11	20	1	4	Do.
12	25	4	.....	Do.
13	20	.....	3	Do.
14	43	3	5	Do.
15	48	.....	.....	Do.
16	35	3	11	Do.
17	27	6	6	Do.
18	21	2	6	Do.
19	39	4	11	Do.
20	12	3	11	Do.
21	2	1	7	Do.
22	13	3	9	Do.
23	12	2	8	Do.
24	1	2	1	Do.
25	5	4	5	Do.
26	4	3	11	Do.
27	14	2	9	Do.
28	18	6	.....	Do.
29	7	.....	11	Do.
30	9	.....	1	Do.
31	7	.....	.....	Do.
Aug. 1	4	.....	.....	Do.
2	1	.....	2	Do.
3	2	.....	1	Do.
4	1	.....	.....	Do.
6	3	.....	.....	Do.
7	3	.....	.....	Do.
9	5	.....	.....	Do.
13	1	.....	.....	Do.
16	8	.....	.....	Do.
17	1	.....	.....	Do
18	1	.....	.....	Do.
19	9	.....	.....	Do.
21	4	.....	.....	Do.
Total	474	52	123	

The late issuance of flies as recorded in 1915 was undoubtedly the result of the issuance of a partial second generation at a time when it was improbable that suitable hosts could be found active in the field. According to the record secured in the breeding experiment in 1918, and cited above, it would seem that the activity of the progeny of the summer generation of parasites is entirely dependent upon the activity of the host. That is, if beetles parasitized by flies of the summer generation immediately become inactive and seek dormancy, the larvæ of the

parasite apparently do likewise. But, on the contrary, if the beetles continue active and feed for a period of 10 days to 2 weeks after becoming parasitized, the larvæ continue to develop until they reach the adult stage, there being thus a partial second summer generation.

HOSTS

Parasites have been bred from adults of *Calosoma sycophanta*, *C. frigidum*, and *C. calidum* collected in the field in New England. Large numbers were bred from the first species because of its great abundance and fewer from the other two species because of their rarity in comparison with *C. sycophanta*. Eggs have also been deposited on *C. wilcoxi* in the breeding cage and the parasite reared to the second or hibernating larval instar. The host which died in hibernation contained two larvæ.

One specimen of *Carabus nemoralis*, collected by P. S. Coffin, Framingham, Mass., May 18, 1916, was dissected and found to contain a large puparium of *Eubiomyia calosomae*. On July 26, 1918, two eggs were deposited by the parasites in a breeding experiment upon a specimen of *C. nemoralis*. This parasitized host later entered the earth for hibernation.

It is very probable that this parasite attacks some species of Calosoma and Carabus occurring in New England, other than the ones here recorded, but the remaining species of these genera are comparatively rare. It is also possible that *Eubiomyia calosomae* may be responsible in a measure for the scarcity of some of the remaining species of the genera.

Larvæ of *Calosoma sycophanta*, *C. frigidum*, and *C. scrutator* were exposed to the flies in the breeding experiments but without results. The flies paid no attention to the larvæ and made no attempt to oviposit upon them. A collection of 1,546 large larvæ of *C. sycophanta* was made during the summer of 1915 and reared to maturity to determine whether *Eubiomyia calosomae* attacks the larvæ, but no parasites were reared. *Doryphora decemlineata*, *Lachnosterna* sp., *Porthetria dispar*, *Euvanessa antiopa*, *Hyphantria cunea*, and *Estigmene acraea* larvæ were also exposed in the breeding cages but without action on the part of the flies.

NATURAL ENEMIES

On November 6, 1915, one dead adult of *Calosoma sycophanta*, collected in Randolph, Mass., contained one puparium of *Eubiomyia calosomae* Coq. On December 14, the puparium was dissected and found to contain a large larva of *Chalcis* sp. as determined by Mr. C. F. W. Muesebeck, formerly of this bureau. Other puparia have been dissected with no further indications of secondary parasitism.

ECONOMIC STATUS OF THE PARASITE

This parasite has two complete generations and a partial third per year, adults issuing in May and June and again in July and August. After a few days the flies which issue early have an abundance of hosts

upon which to oviposit because of the emergence of *Calosoma sycophanta* from hibernation. The summer generations issuing in July and August are more abundant than the first generation, but they find comparatively few beetles to parasitize because the beetles begin to enter hibernation about July 15 and decrease very rapidly in numbers above ground after that date. There is an abundance of flies issuing after this period that must perish for want of a host unless they attack some host other than species of Calosoma or Carabus. This probably accounts for the present limits to the increase of the parasite.

Additional recorded hosts for this parasite are comparatively rare in the New England section where *Calosoma sycophanta* abounds. It is difficult to predict the future effect of the species on *C. sycophanta* since future rarity or abundance of other related hosts may have a great bearing on the subject; but it is believed that the parasite will not become much more abundant than it is at present. The average of 3.3 per cent parasitism secured from the small collections of *C. calidum* indicates that the parasite is more effective on *C. calidum* than on *C. sycophanta*, upon which the highest parasitism was 3.4 per cent, secured in 1916, or an average of 1.12 per cent for a period of several years. Should *C. calidum* by chance become very abundant in eastern Massachusetts and southern New Hampshire where *C. sycophanta* is now very abundant, the depredations of the parasite might also increase, since a longer breeding season for the latter would be furnished. *C. calidum* emerges from hibernation in the territory mentioned about May 1 to 15, and *C. sycophanta* about June 1 to 15. It is therefore apparent that the two species of hosts which occur abundantly in the same locality might increase the abundance of the parasite materially.

SUMMARY

Eubiomyia calosomae has two full generations per year and a partial third under favorable seasonal conditions. The eggs hatch in from 3 to 24 hours, the larvæ develop in from 9 to 12 days, and the pupæ in from 9 to 18 days, making it possible for a generation to develop fully in from 20 to 25 days.

The first record of the rearing of this parasite in this country was from a specimen of *Calosoma calidum* in 1896. If one judges from the literature on the species and the small representation of specimens in the collections which were taken with the net, one would infer that the species is rare in the East; but this may be due to the peculiar habits of the adults in the field, which are not well known. The species seems to have attracted little attention between 1896 and 1912, when it was first bred from *C. sycophanta*, six years after the successful introduction of the latter species into New England. During the seasons from 1915 to 1918, over which period a study was made of its life history, the highest parasitism upon *C. sycophanta* was 3.4 per cent in 1916,

and an average of 4.4 per cent upon *C. calidum* for a period of years. The abundance of the parasite of the summer generations occurs at a time when adults of *C. sycophanta* and other species of Calosoma are beginning to enter the earth for a period of dormancy followed by hibernation. This doubtless tends to limit the opportunity for increase under present conditions. The data thus far accumulated show that the parasite has not yet caused a serious handicap to the abundance and usefulness of *C. sycophanta* in New England.

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PLATE 58

Eubiomyia calosomae:

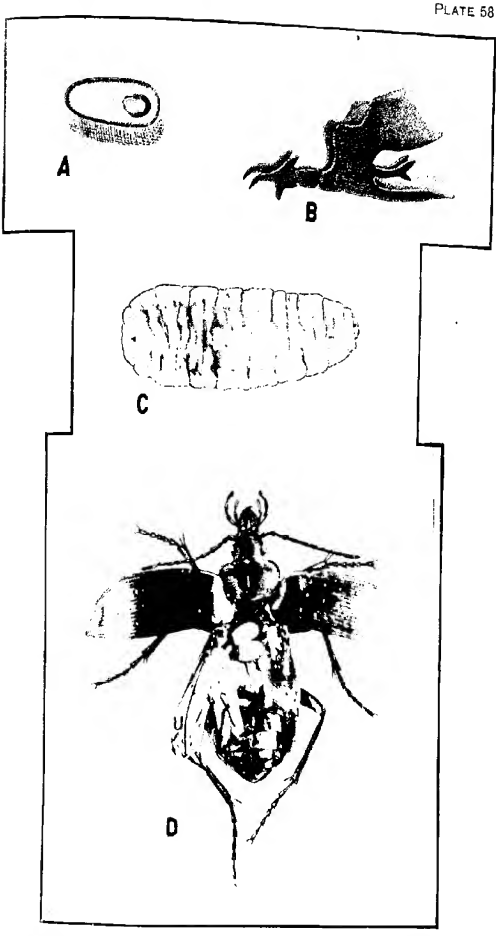
A.—Egg, showing flat side and exit hole of larva. Much enlarged.

B.—Mouth hook of third-stage larva. Much enlarged.

C.—Third-stage larva after preservation in alcohol. Enlarged.

D.—Adult of *Calosoma sycophanta* containing two second-stage or hibernating larvæ of Eubiomyia. × 1¾.

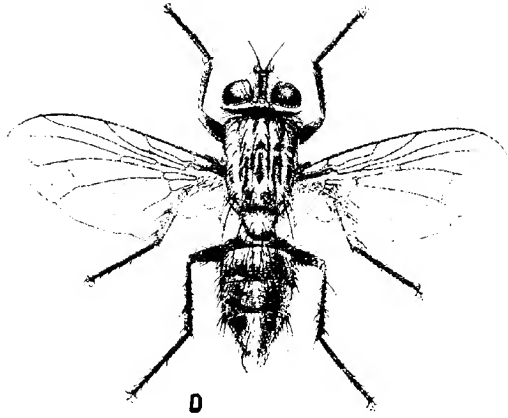
PLATE 58



A

B

C



D

PLATE 59

Eubiomyia calosomae:

A.—Puparium. × 7.
B.—Anal stigmata of puparium from slide mount. Much enlarged.
C.—Section of spine area on segment of puparium. Much enlarged.
D.—Adult female. × 7.

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